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EFFECTS OF AGRICULTURE ON STREAM FAUNA IN CENTRAL INDIANA

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16. ABSTRACT

From 1978 through 1980 the benthic macroinvertebrate and fish communities of three stream systems in Central Indiana were examined. The objective of this study was to describe the organization of these communities in relation to different land use. The influence of agriculture on the 14 stream segments ranged from virtually none to intense, and included some drainage from animal feed lots. The results of the study suggest the pattern of change caused by the increasing development of agriculture in small watershed streams. Initially agriculture may lead to an expanded biomass of fish and macroinvertebrates without causing a large compositional re-organization. However, chironomids assume a dominant role for the macroinvertebrates while other benthic groups become secondary in importance. These benthic changes appear to occur without strongly influencing the fish community, except for an increase in standing crop. Further development of agricultural stresses causes a sudden, pronounced shift in the composition of the fish community. Communities dominated by insectivores and piscivores (centrarchids in these streams) are converted to communities dominated by omnivores, herbivores, and detritivores. This alteration may occur with little or no change in standing crop biomass. At this stage the density of non-chironomid insect larvae becomes reduced. The near-stream riparian part of the watershed is vital to the maintenance of healthy aquatic communities, acting as a buffer between plowed fields and farm animals and the aquatic system.

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ABSTRACT

From 1978 through 1980 the benthic macroinvertebrate and fish communities of three stream systems in Central Indiana were examined. The objective of this study was to describe the organization of these communities in relation to different land use. The influence of agriculture on the 14 stream segments ranged from virtually none to intense, and included some drainage from animal feed lots. The results of the study suggest the pattern of change caused by the increasing development of agriculture in small watershed streams.

Initially agriculture may lead to an expanded biomass of fish and macroinvertebrates without causing a large compositional reorganization. However, chironomids assume a dominant role for the macroinvertebrates while other benthic groups become secondary in importance. These benthic changes appear to occur without strongly influencing the fish community, except for an increase in standing crop.

Further development of agricultural stresses causes a sudden, pronounced shift in the composition of the fish community. Communities dominated by insectivores and piscivores (centrarchids in these streams) are converted to communities dominated by omnivores, herbivores, and detritivores. This alteration may occur with little or no change in standing crop biomass. At this stage the density of non-chironomid insect larvae becomes reduced.

Additional stress, such as organic loading from animal feed lots, causes further reductions in diversity and density of macroinvertebrates and in lowered standing crops of fish.

The near-stream, riparian part of the watershed is vital to the maintenance of healthy aquatic communities, acting as a buffer between plowed fields and farm animals and the aquatic system.

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INTRODUCTION

The realistic assessment of stream communities necessitates the recognition of several ecological and environmental factors. Habitat structure is a major determinant of the types and numbers of species found inhabiting a stream. MacArthur (1961, 1964, 1966) pioneered studies on the relationship between community diversity and habitat structure, and more recently Gorman and Karr (1978) have noted the direct relationship between habitat diversity and fish species diversity. Seasonal hydrologic events, i.e. flash flooding also have a profound effect on a stream's biotic composition. Flooding and the concurrent heavy silt loads may serve to limit the abundance of certain species of fish (Starrett 1951), while limiting the spawning potential of others (Cleary 1956). Nevertheless, Gerking (1950) noted the stability of a stream fish population following a flash flood.

In addition to naturally occurring environmental stresses, aquatic organisms must also contend with those inflicted by man. Point sources of pollution, i.e. sewage and industrial effluents, have a major impact on stream organisms (Hynes 1974), and their affect on fish is well documented (Tsai 1975).

Intensive alterations of surface lands during the past century in response to increased agricultural demands have also had a profound effect on the biota of the streams draining these areas. Silt, the major pollutant of these agricultural areas, has been implicated as the principal factor in altering the fish communities of many midwestern streams (Trautman 1957, Cross 1967, Smith 1968, 1971, and Gammon 1977).

A demonstration project on Black Creek in Allen County, Indiana, was established to study how non-point sources of pollution could best be controlled (Lake and Morrison 1977). Karr and Schlosser (1978) concluded that through the maintenance of natural channel morphology and nearstream vegetation an equilibrium can be established leading to "more productive, diverse and stable stream biotas."

Using the information and experience gained from the Black Creek study, a Model Implementation Program (MIP) was initiated by the U. S. Environmental Protection Agency and the U. S. Department of Agriculture to study the effects of non-point source pollution on stream biota. The goal of this project is to monitor any faunal changes that might occur in the study stream in response to the institution of good land-use practices in the respective watersheds.

The watersheds of Eagle Creek and Stotts Creek, both of which drain into the West Fork of the White River, were chosen as the experimental streams, with nearby Rattlesnake Creek being added to serve as a control stream (Figure 1).

The objectives of this study were to determine the quality and quantity of the macroinvertebrate and fish communities of Eagle, Stotts, and Rattlesnake Creeks, and to describe their community organization in relation to land use.

CONCLUSIONS

Stream fauna can be used to assess the degree to which agriculture influences water quality; the results of this study indicates the pattern of changes which attend the increasing agricultural development of a forested watershed. Parallel evaluations were obtained both from fish and macroinvertebrates for most situations, but more was learned from a combination of the two groups than from either one alone.

Standing crop estimates of fish were not, in themselves, of great value in evaluating chronic agricultural effects, although depressions in biomass occurred in response to sporadic problems with animal feed lots and to chronic problems with a chemical recycling plant and land-fill. The best indicator of agricultural effects on fish is the proportion of piscivores (primarily centrarchids in the study streams) and insectivores in the fish community in combination with biomass estimates.

Initially agriculture may lead to increased biomass of fish and macroinvertebrates without changing community composition. As agricultural development expands, however, chironomids assume a dominant role while other macrobenthic groups decline in importance. The fish community remains dominated by piscivores and insectivores and may actually increase in biomass. Continued development of agriculture causes a sudden, pronounced shift in the fish community as piscivores and then insectivores become reduced in abundance and the communities become dominated by omnivores, detritivores, and herbivores. This alteration occurs with little or no change in standing crop. The density of non-chironomid insect families become much reduced.

Recognition of the different velocities of change which occur as the result of agricultural development is vital to evaluating the "health" of stream communities. A stream which appears to be excellent from a fishing standpoint may stand on the brink of sudden biotic changes. Likewise, a stream which has lost its piscivores may, with some reasonable degree of assistance, be returned to a much more desirable biotic state.

RECOMMENDATIONS

Any program designed to improve water quality in agricultural watersheds should identify and evaluate all potential areas of point-source pollution, including animal feed lots, land-fills, etc. A substantial improvement in water quality could accrue from intensified efforts to examine and regulate these sites. A related problem which is common in the midwest is the pasturing of farm animals with free access to streams. The cost-benefits of fencing or otherwise excluding animals should be examined.

Following the control of point-source problems, we recommend the preservation and/or establishment of permanent riparian forests to act as buffer zones between cropland or pasture and streams. Research should be undertaken to determine the minimum effective width for a variety of streams. Efforts of farmers to increase food production are most in conflict with the goals of water quality improvement with respect to this riparian zone, which is rapidly disappearing in many watersheds.

The third area of agriculture which strongly affects water quality is that of cultivated fields or cropland. All segments of society are in agreement about the desirability of reducing erosion and confining soil, nutrients, herbicides, and pesticides to tilled fields. The current beginning revolution in tillage practices and the widespread adoption of best management practices could substantially reduce the entry of non-point source pollutants from croplands to streams and thereby benefit aquatic life.

In conjunction with the above efforts, a general assessment of biotic communities of agricultural watersheds should be undertaken. Much information which already exists in the files of state Departments of Fish and Wildlife and in scientific literature may be reviewed and interpreted anew. Additional new studies of important streams should be made. Priority rankings of stream systems should follow with the goal of maintaining those having good water quality and instituting programs for those which appear to be most amenable to improvement.

THE STUDY STREAMS

The three study streams (Figure 1) are readily distinguished from each other by their geologic formations and soil associations. The Eagle Creek watershed encompasses portions of four counties in central Indiana including Hamilton, Boone, Hendricks, and Marion Counties. It lies within the Tipton Till Plain (Schneider 1966), with New Albany shale and Middle Devonian limestones and dolomites comprising its major bedrock units. Unconsolidated deposits are represented by glacial advances. Miami-Crosby-Brookston is the predominant soil association and is distinguished as being nearly level to moderately steep and by having medium textured, loamy and silty soils formed in glacial till. The main limitation for agricultural use of this association is erosion (Hays and Preston 1979). Because of the soil associations and the topography of the Eagle Creek watershed, it is considered to have a low to medium potential for erosion (Clark 1980). This assessment of potential erodibility neglects the varying degrees and types of ground cover which may compensate for the erodibility of the soils. The Eagle Creek watershed has 70% and 13.5% of its ground cover as cropland and forest, respectively.

The Stotts Creek watershed lies within Morgan and Johnson Counties and is located on the southern boundary of the Tipton Till Plain and the Wisconsin glacial advances. The bedrock unit is the Borden Group which is principally composed of gray argillaceous siltstones and shales, sandstones and some interbedded limestones. Like Eagle Creek, the unconsolidated deposits consist of glacial tills. The principal soil associations are the Miami-Crosby, Miami-Hennepin, Crosby-Brookston and Miami-Fincastle. These range from nearly level to strongly sloping, medium textured soils formed in glacial till. Erosion is considered a hazard on slopes of 2% or more. The soil associations and topography produce a high potential for erosion (Clark 1980) but, 34.5% of the watershed is forested and 58.4% is in crops. Thus, ground cover reduces the potentially high erodibility to a somewhat lower actual erodibility.

Rattlesnake Creek, in Owen County, originates in the Owen Putnam State Forest, and lies within the Crawford Upland. Its principal bedrock unit, the Blue River Group, is composed largely of carbonate rocks with significant amounts of gypsum, anhydrite, shale and calcaneous sandstone. Glacial till of the Illinoian age is the principal unconsolidated deposit. Soil associations include Cincinnati-Vigo-Ava; sloping, well-drained, silty soils with fragipans, and Wellston-Zanesville-Berks which are distinguished as being sloping, well-drained silty soils in loose and weathered shale and sandstone. Rattlesnake Creek is heavily wooded which subsequently reduces the potentially very high erodibility projected by Clark (1980) based on soil associations and topography.

The stream beds and flood plains of Eagle, Stotts, and Rattlesnake Creeks are of the Genesse-Shoals Association and are characterized as being nearly level, medium textured soils formed in alluvium on bottom lands. Table 1 lists some of the principal morphometric features of the study streams.

Table 1. Morphometry of streams sampled in the Eagle Creek, Stotts Creek and Rattlesnake Creek watersheds (Fisher 1979).

Stream	Drainage area(km^2)	Total length(km)	Elevation change(m)	Channel gradient(%)	Sinuosity
Eagle Creek	418.4	46.6	49.4	0.127	1.13
School Branch	22.7	7.6	28.2	0.376	1.30
Fishback Creek	53.8	17.3	36.5	0.211	1.40
Little Eagle Creek	75.9	14.2	57.6	0.404	1.12
Finley Creek	25.2	12.0	21.2	0.177	1.10
Mounts Run	41.2	13.9	27.3	0.196	1.14
Stotts Creek	155.6*	25.5	9.1	0.165	1.28
South Prong		19.2	42.8	0.220	1.18
North Prong	56.7	14.6	42.4	0.289	1.34
Rattlesnake Creek	65.2	16.9	27.3	0.162	1.20

*drainage area of mainstem of Stotts Creek and South Prong.

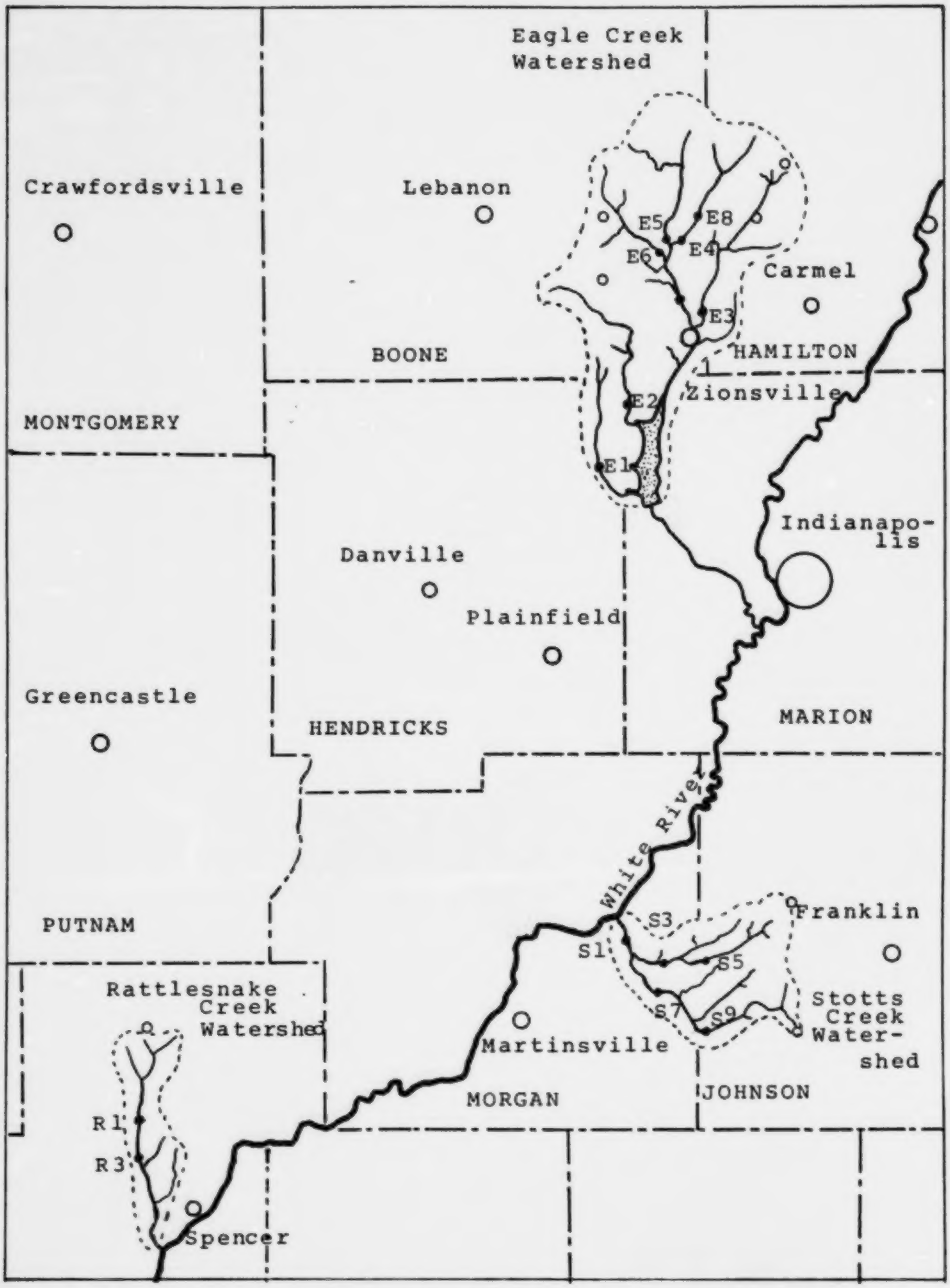
Eagle Creek
Watershed
Crawfordsville
Lebanon
E5
E8
E6
E4
Carmel
E3
BOONE
HAMILTON
E2
Zionsville
MONTGOMERY
E1
Indianapolis
Danville
Plainfield
Greencastle
HENDRICKS
MARION
White River
PUTNAM
S3
Franklin
S1
S5
Rattlesnake
Creek
Watershed
S7
S9
Stotts
Creek
Watershed
Martinsville
MORGAN
JOHNSON
R1
R3
Spencer

Figure 1: Central Indiana showing locations of stations designated for biological sampling. ○ = urban areas • = sampling sites.

Eagle Creek watershed (Figure 1) has a drainage area of 638.22 km^2. It consists of a main stem and numerous first and second order tributaries. Unlike the other watersheds studied, Eagle Creek has a large reservoir at its lower end.

Sampling sites were selected on the basis of similarity of physical dimensions, riparian characteristics, and accessibility. Eight benthic and seven fish sampling sites were used in this watershed. Fish and benthic sampling sites were in close proximity to each other. The E1, E2, E3, E4, and E6 sampling stations were located at the lower end of tributaries. E5 and E7, the latter a benthic site only, were located on the main stem. At the upper end of Finley Creek fish site E8 was established late in 1978, but benthic sampling was not conducted there until 1979.

Stotts Creek (Figure 1) drains an area of 213.30 km^2. Six benthic and five fish collection sites were established in this watershed. Two benthic (S1 and S2) and one fish (S1) sampling stations were established downstream from the junction of the North and South prongs of Stotts Creek. The North prong has a downstream (S3) and an upstream station (S5). The South prong also has a downstream station (S7) and an upstream station (S9).

Rattlesnake Creek (Figure 1) was sampled at two adjacent sites in 1978 for benthic organisms (R1 and R2) in the largely forested, hilly upper section of the elongated watershed. Fish sampling sites were initially established in conjunction with the benthic stations, but in 1979,R2 was replaced by a new site (R3) in the lower section to better sample the lower section which is flanked by some agricultural fields. The Rattlesnake Creek watershed (65.24 km^2) is smaller than Stotts or Eagle Creek and is influenced to a much smaller degree than either Stotts or Eagle Creek, by agriculture.

MATERIALS AND METHODS

FISH

Fish were collected using a 30-foot electric seine with 2-foot, bare copper wire electrodes powered by a 115 VAC, 1350 Watt generator which was floated on a styrofoam pad and pulled behind the seine. Hand-held electrodes at each end were used to probe undercut banks and roots. In practice the seine was stretched across the stream at the downstream margin of a pool and moved gradually upstream. This apparatus is similar to the one used by Larimore (1961). Generally the seine was operated by five persons; one at each end to probe and net; and three netters one of whom pulled the generator and another pulled a floating net. Fish were netted as they were stunned and immobilized by the electric field and were placed immediately in the live-net. At the upstream end of the pool, electrofishing was continued as far as possible into the riffle so that both riffle and pool communities were sampled.

At the completion of the collecting run, the gear and netters returned to the lower boundary of the pool where the fish were identified to species, weighed and measured. In some instances, field identification was not possible so these fish, primarily minnows and darters, were preserved in 5% formalin and identified later. After processing, the fish were placed in a holding net while a second and third electrofishing pass were made.

Standing crop was estimated using the successive removal method (DeLury 1947). Approximately half of the biomass in each pool was captured per pass and the catches declined accordingly. A regression of catch in weight per pass versus the previous cumulative catch yielded an estimate of the total standing crop by extrapolation to zero catch. The use of numbers of fish was less satisfactory than biomass. Standing crop by weight yielded a more reliable, less erratic estimate because of the tendency for larger fish to be more susceptible to capture by this method.

In addition to standing crop estimates, Shannon diversity indices based on weights and numbers, and evenness values were computed for each sample and for the combined yearly data. Diversity was calculated for each site using the Shannon formula, a type I heterogenity index which combines species richness and evenness, and is most sensitive to changes in the rare species of the sample (Peet 1974). Both numerical density data and biomass data were calculated according to the formula:

$$H' = -\sum \left(\frac{ni}{N}\right) \mathrm{Ln} \left(\frac{ni}{N}\right)$$

where ni equals the numbers or weight for individual species, and N is the total number or weight of the sample. Evenness was computed using the formula described by Pielou (1975):

$$J' = \frac{H'}{\mathrm{Ln}S}$$

where H' is the Shannon index of diversity, and S is the total number of species in the sampled community.

A cluster analysis was performed on the proportion by weight of each species in each collection of fish. An arcsine transformation preceded the actual cluster analysis. A matrix of correlation coefficients in the Q-mode was computed to show similarities between stations on the basis of their contained species. The correlation matrix was then clustered using the unweighted pair-group method with arithmetic averages. A coefficient of cophenetic correlation was also computed to measure the amount of distortion introduced during clustering. The same procedure was followed for each year separately and all three years together.

Stream habitat was evaluated in 1978 for five dimensions at each study site: predominant substrate type, flow, mean depth, amount of instream cover, and canopy coverage. Five categories were recognized in each dimension and values, ranging from one to five, were assigned to each respective group (Appendix A).

BENTHIC MACROINVERTEBRATES

Macroinvertebrates were collected with a 1-ft^2 (.0920 m^2) Surber sampler and a long handled dip net. Three replicate samples were collected at each station with each of the sampling devices yielding a total of six samples per station. With some exceptions, sampling was conducted once a month from May through August and also in October, in 1978, 1979, and 1980.

Surber collections were made by seating the sampler against the substrate of the riffle and turning the bottom substrate to a depth of 15 cm with a small garden shovel. This process was continued for approximately 2 minutes, and served to dislodge the macroinvertebrates that were subsequently carried by the stream current into the net of the Surber. The sample was then washed into a bucket of stream water and strained through a No. 60 sieve (250 um openings). Each sample was then transferred to a prelabeled container and preserved with 80% denatured ethanol containing rose bengal stain.

Sample collections with the dip net were made along the stream bank by scooping along a distance of 10 meters. The dip net samples were washed into a bucket of stream water which was then poured through a No. 35 sieve (425 um openings). The samples were transferred to prelabeled containers and preserved in the same manner as the Surber samples.

The preserved samples were brought into the laboratory where they were sorted with the aid of dissecting microscopes, tallied with counters and identified to family. The taxonomic references used included Edmunds, et al (1976), Johannson (1970), Merritt and Cummins (1978), Needham and Claassen (1925), Pennak (1978), Ross (1944), and Wiggins (1978). Wet weight of the animals in each sample was determined for each taxonomic group to the nearest .001 grams using a Mettler P1 200 digital balance. The counts and weights were stored on a computer disk file for statistical analysis. These data were used to calculate biomass and density. Diversity indices were calculated for the biomass and density at both the order and family levels using the Shannon diversity formula. Statistical tests were performed using the two sample t test.

STREAM MORPHOLOGY, HABITAT, AND STREAM BANK VEGETATIONAL PATTERNS

During the period from mid-May to mid-August 1979, each major tributary of Stotts and Eagle Creeks and the single channel of Rattlesnake Creek was examined at four or five sites for the following parameters: (1) stream habitat, (2) channel morphology, and (3) adjacent land use. All sites were located in the lower half of the drainage basins.

Stream habitat structure consisted of eight parameters, including for both riffles and pools such characteristics as length, width, depth, flow, aquatic flora, bottom composition, and cover. Point determinations were made with a meter pole at 5 m intervals moving upstream, a technique similar to that used by Gorman and Karr (1978). The deepest part examined from each watershed was assigned a value of 100 and the mean depth of other pools rates as a percentage of this reference depth. Flow rates were determined with a Mikasa flow meter. Seven categories of bottom composition were identified using the Wentworth scale: boulders (256 mm), cobble (64-256 mm), pebble (4.0-64 mm), granules (2.0-4.0 mm), sand (0.06-2.0 mm), and silt (0.000-0.06 mm).

Bank-canopy structure consisted of seven parameters: bank height, bank slope, bank undercut, bank composition and percent, percent canopy, and canopy height.

Bank slope was divided into three categories: gradual (0-30 cm), moderate 31-60 cm), and steep (69-90 cm). Bank composition consisted of ten categories: bare soil, exposed roots, grass, trees, samplings, willow shrubs, sawgrass, rocks, tree debris, and non-willow shrubs.

Two aspects of land use were examined: (1) the predominant type of land use adjacent to the stream, and (2) the presence or absence of an interface or buffer strip immediately adjacent to the stream. The various types of predominant land use recognized were (1) cultivated fields of soybeans or corn, (2) meadows, (3) woods and forests, and (4) residential areas. Buffer strips, when present, consisted of either grasses, scattered trees, or woods. This study was conducted without regard to the width of the buffer strip.

RESULTS

FISH

During the course of this 3- year study 35,043 fish were collected (Appendix B). Of the 50 species collected, 8 comprised 85% of the total number caught: bluntnose minnow, central stoneroller, creek chub, striped shiner, silverjaw minnow, common white sucker, johnny darter and orangethroat darter (Table 2). Mean summer standing crops ranged from 30-320 kg/ha.

Point Source Problems

Point source disturbances, both spatial and temporal, profoundly affected the fish populations at some collecting stations and required evaluation before nonpoint source (NPS) effects could be assessed. Weather affected the results, especially in 1979 when floods during July and August caused a marked temporary depression in the standing crops of fish with the single exception of E4. Here the standing crop increased from 45.1 kg/ha before the flood to 129.8 after the flood.

In addition to weather, some acute and chronic point source perturbations also influenced the results. In the Eagle Creek watershed four areas of non-agricultural perturbations existed. Above the E4 site a landfill and adjacent chemical recycling plant influenced the water quality and stream habitat. During the summer of 1978 a great deal of mud covered the bottom at this site. A luxurious growth of sewage fungus developed in 1979 prior to the flood, and in 1980 the bottom substrate appeared to be normal, but low densities of fish were still present.

Bridge construction disturbed station E1 in 1979 and 1980 when this area, including the streambed, was bulldozed.

Sampling station E3 could have been influenced by a septic tank seepage problem in the Eagleton area and fairly extensive stream channel alteration including numerous lateral ponds through the middle portion of the watershed. It is possible that rapid urbanization within both School Branch and Fishback Creek watersheds influenced our results, but the degree of influence was not possible to determine.

Four of the five sampling stations on Stotts Creek were periodically influenced impacted by known point-source pollution.

Table 2: Total catches of fish by electrofishing in three central Indiana stream systems during summers of 1978, 1979, and 1980. +indicates <0.1%

Species	Eagle Creek No.	Eagle Creek (%)	Stotts Creek No.	Stotts Creek (%)	Rattlesnake Crk. No.	Rattlesnake Crk. (%)
Am. Brook Lamprey(D)*	-	-	-	-	20	(0.6)
Silver Lamprey(P)	4	(+)	-	-	-	-
Chestnut Lamprey(P)	-	-	-	-	4	(0.1)
Gizzard shad(H)	35	(0.3)	3	(+)	-	-
Grass pickerel(P)	62	(0.5)	-	-	16	(0.5)
Black bullhead(O)	72	(0.5)	3	(+)	-	-
Yellow bullhead(O)	30	(0.2)	27	(0.1)	-	-
Brindled madtom(I)	-	-	18	(+)	-	-
Blackstripe topminnow(I)	31	(0.2)	-	-	-	-
Brook silversides(I)	8	(+)	-	-	-	-
Goldfish(O)	-	-	1	(+)	-	-
Carp(O)	9	(+)	2	(+)	-	-
Common white sucker(I)	642	(4.8)	1080	(5.1)	15	(0.5)
No. Hogsucker(I)	-	-	324	(1.5)	172	(5.2)
Spotted sucker(I)	9	(+)	-	-	-	-
Silver redhorse(I)	4	(+)	2	(+)	-	-
Black redhorse(I)	-	-	112	(0.5)	136	(4.1)
Golden redhorse(I)	6	(+)	170	(0.8)	56	(1.7)
Shorthead redhorse(I)	-	-	4	(+)	-	-
Spotfin shiner(I)	1	(+)	79	(0.4)	34	(1.0)
Sand shiner(I)	-	-	569	(2.7)	67	(2.0)
Mimic shiner(I)	-	-	6	(+)	3	(+)
Bluntnose minnow(D)	2387	(17.8)	5933	(27.8)	391	(0.9)
Stoneroller(H)	2751	(20.5)	5684	(26.6)	436	(13.2)
Creek chub(I)	2506	(18.7)	1879	(8.8)	288	(8.8)
Blacknose dace(I)	-	-	123	(0.6)	4	(0.1)
Suckermouth minnow(I)	3	(+)	21	(+)	20	(0.6)
So. Redbellied dace(H)	5	(+)	10	(+)	-	-
Silverjaw minnow(I)	75	(0.6)	1528	(7.2)	154	(4.7)
Striped shiner(I)	658	(4.9)	1172	(5.5)	416	(12.6)
Bigeye chub(I)	-	-	-	-	42	(1.3)
Steel shiner(I)	-	-	1	(+)	4	(0.1)
Redfin shiner(I)	128	(1.0)	106	(0.5)	52	(1.6)
Rock bass(P)	59	(0.4)	-	-	119	(3.6)

Table 2: (continued)

Species	Eagle Creek		Stotts Creek		Rattlesnake Crk.	
	No.	(%)	No.	(%)	No.	(%)
Warmouth(P)	-	-	1	(+)	-	-
Green sunfish(P)	155	(1.2)	166	(0.8)	16	(0.5)
Bluegill(P)	165	(1.2)	142	(0.7)	23	(0.7)
Longear sunfish(P)	197	(1.5)	69	(0.3)	135	(4.1)
Smallmouth bass(P)	3	(+)	45	(0.2)	10	(0.3)
Largemouth bass(P)	47	(0.4)	21	(+)	19	(0.6)
White crappie(P)	57	(0.4)	4	(+)	-	-
Black crappie(P)	2	(+)	-	-	-	-
Spotted bass(P)	46	(0.4)	100	(0.5)	6	(0.2)
Greenside darter(I)	3	(+)	122	(0.6)	34	(1.0)
Fantail darter(I)	-	-	35	(0.2)	-	-
Johnny darter(I)	734	(5.5)	330	(1.5)	154	(4.7)
Log Perch(I)	199	(1.5)	-	-	-	-
Blackside darter(I)	10	(+)	-	-	9	(0.3)
Rainbow darter(I)	160	(1.2)	335	(1.6)	240	(7.3)
Orangethroat darter(I)	757	(5.7)	892	(4.2)	56	(1.7)
Mottled sculpin(I)	320	(2.4)	-	-	113	(3.4)
Creek chubsucker(I)	42	(0.3)	1	(+)	3	(0.1)
Unidentified	1	(+)	4	(+)	9	(0.3)
Total No.	13,395		21,357		3,291	
No. Species	39		40		35	

*Trophic status: P=piscivore, I=insectivore, H=herbivore, and O=omnivore

At sampling station S7 a major fish kill occurred in 1979 as a result of discharge from a swine farm. The specific cause was not determined. In 1980 low densities of fish indicated that the site had not recovered or was still being influenced by such discharges. It is uncertain whether or not the station S2 was also negatively influenced.

A discharge from the swine farm on Skunk Hollow resulted in a minor fish kill in June 1980. Both S1 and S3 could have been influenced by swine waste, but no fish kills seem to have resulted at our sampling sites. In August 1980 a fish kill occurred on the North prong of Stotts Creek near sampling site S5, the cause of which was not ascertained.

Except for limited agricultural utilization along Rattlesnake Creek no known perturbations were noted during the period of study.

Utilizing the habitat information, a ranked-score index of habitat structure was devised in which the scores of each category for all five dimensions were summed producing an overall habitat rating for each study site (Appendix A). The theoretical minimum and maximum were 5 and 25, respectively, while the actual range was 11-17 for our sampling sites. Most sites rated from 12 to 15, reflecting the fulfillment of our subjective criterion for homogeneity of sampling stations.

Regression and correlation analyses were used to determine the relationship (1) between habitat structure (defined by the ranked-score index) and species diversity, i.e. Shannon diversity, and (2) between habitat structure and species diversity and abundance.

Finley Creek (E4) was omitted from the analyses because of the obvious influence of an active land-fill operation, located immediately upstream from our collection site, on the water quality of this segment of the stream. The correlation coefficient (r) for the comparison of habitat structure with Shannon diversity was positive and significant ($p < 0.05$).

Rattlesnake Creek

Trophic level analysis of the fish populations in Rattlesnake Creek showed that 70-80% of the biomass consisted of piscivores and insectivores. Omnivores were the next largest group comprising 27.1% and 11.4% of the biomass at R1 and R3, respectively. Herbivores did not exceed 6% of the biomass at either site (Tables 3 and 4). The downstream sampling stations (R3) had a much higher standing crop (224 kg/ha) than the upstream station (73 kg/ha). The difference between these two sites was mainly attributable to the greater abundance of northern hogsuckers, black and golden redhorse, and longear sunfish.

Eagle Creek

Standing crop values for Eagle Creek range from 100 to 200 kg/ha with few exceptions (Table 3). Low densities were consistently found at the E4 site on Finley Branch. E8, an upstream sampling station, had a mean standing crop of 252 kg/ha while E4 had a mean standing crop of 68 kg/ha, only 27% as great as the upstream site. In addition to a depressed density the diversity at E4 was consistently lower than any other site

Table 3: Estimated standing crop of fish (kg/ha) during the summer in Rattlesnake, Stotts, and Eagle Creeks.

Sampling Site	1978		1979		1980		1978-80
	June	Aug.	June	Aug.	June	Aug.	Mean
R-1	128	90	62	71	46	41	73
R-3	69	73	161	95	376	265	173
S-1	109	106	159	-	18	61	91
S-3	187	242	294	97	161	184	194
S-5	117	157	278	207	181	124	177
S-7	100	105	65	1.3	9	133	69
S-9	148	99	339	56	117	88	141
E-1	80	62	58	25	300	21	91
E-2	99	142	110	47	467	48	152
E-3	89	68	196	58	214	41	111
E-4	44	63	45	130	79	49	68
E-5	162	151	453	107	307	108	215
E-6	161	210	153	138	105	87	142
E-8	-	269	405	63	213	308	252

Table 4: Mean composition (% weight) of the fish communities of Rattlesnake, Stotts, and Eagle Creeks based on trophic categories, 1978-1980.

Site	% Piscivores	% Insectivores	% Herbivores	% Omnivores	% Detritivores
			Rattlesnake Creek		
R-1	28.2	42.6	2.1	23.8	3.3
R-3	22.6	60.7	8.7	7.0	1.0
			Stotts Creek		
S-1	17.3	54.3	6.6	20.1	6.3
S-3	7.9	32.6	14.4	38.1	6.2
S-5	25.5	37.5	15.6	21.8	3.1
S-7	2.4	27.9	32.9	36.8	6.7
S-9	3.5	33.5	21.8	38.6	9.0
			Eagle Creek		
E-1	11.3	32.1	8.6	46.3	0.9
E-2	10.4	35.6	16.1	32.6	5.5
E-3	9.5	26.1	16.9	40.7	6.3
E-4	12.0	16.1	24.0	42.1	5.9
E-5	26.2	47.0	6.4	19.1	1.6
E-6	30.5	49.9	12.4	7.2	3.2
E-8	10.5	26.1	7.5	54.0	2.1
E-6(1981)	26.8	61.7	1.3	-	10.2

within the watershed (1.0-2.2). Diversities for other stations were between 1.5 and 2.2 with a mean of 1.8 (Table 5).

Three fourths of the 13,395 fish captured belong to 7 species: bluntnose minnow, stoneroller, creek chub, striped shiner, common white sucker, johnny darter, and orangethroat darter. In addition, 32 less common species were captured. The most prominent trophic groups were piscivores and insectivores. These two groups generally comprised 30-80% of the biomass at the sampling stations on Eagle Creek (Table 4). Omnivores were also prominent with E8 having the highest percentage of omnivores (56.1%) and E5 the lowest (20.7%). Herbivores were the least prominent trophic group, comprising an average of 13% of the biomass.

Piscivores and insectivores at E5 made up 70-85% of the biomass while the percentages of herbivores and omnivores were low (Table 4). The Mounts Run community (E6) also has a similar trophic structure. School Branch (E1) and Fishback Creek (E2) were similar to each other and very stable over the period of study. Omnivores comprised 26-58% ($\bar{x}$ = 39%) and P+I = 40-50%. Following these sites were Little Eagle Creek (E3) and the monitoring site on Finley Branch (E8) with 35-45% piscivores and insectivores. The group comprising most of the remaining population was omnivores with 30-55% of the biomass. Piscivores and insectivores were consistently low (P+I = 15-30%) throughout the study while herbivores and omnivores combined for 50-75% of the biomass.

Mean weights of the fish ranged from 10-20 gm with an overall average of 16 gm. A low mean weight was found at E1 (8.5 gm) and a high of 49.7 gm at E5.

Stotts Creek

Stotts Creek yielded 21,357 fish from 40 species; 88% of the total catch was composed of 8 species: bluntnose minnow, stoneroller, creek chub, silverjaw minnow, striped shiner, orangethroat darter, sand shiner, and common white sucker.

The average fish weighed 8 gm, only half as much as at either Eagle or Rattlesnake Creeks. The smallest mean weight was found at S7 (3.8 gm) and the largest at S5 (18 gm).

The standing crop generally ranged from 100-200 kg/ha. The lowest densities were found at S7 during 1979 and 1980. These values were 33 and 71 kg/ha, respectively. The S1 site was also low in 1980 (39 kg/ha) after having normal densities of 108 kg/ha in 1978 and 159 kg/ha in 1979. The highest standing crop of 242 kg/ha was obtained at S5 during the summer of 1979.

Fish diversity at Stotts Creek averaged 1.96 with most collections ranging from 1.7 to 2.3. Unusually low values occurred

Table 5: Mean Shannon diversity values for fish, 1978-1980*

Site	Shannon Diversity No.			Shannon Diversity No.		
	1978	1979	1980	1978	1979	1980
E1	2.13	1.52	1.66	1.56	1.22	1.53
E2	2.02	1.88	1.84	1.80	1.75	1.77
E3	1.88	1.90	1.82	1.69	1.73	1.72
E4	2.18	1.30	1.66	1.82	1.06	1.34
E5	2.70	1.87	2.07	1.67	1.47	1.67
E6	2.23	2.09	1.80	2.12	1.97	1.49
E8	2.30	1.93	1.85	1.61	1.42	1.50
S1	2.00	2.12*	1.83	2.04	1.93	1.46
S3	1.98	2.15	2.10	2.16	2.29	1.98
S5	2.07	1.81	1.85	3.05	1.79	1.65
S7	2.06	1.87	1.63	2.08	1.75	1.42*
S9	3.17	1.67	1.90	1.85	1.47	1.80
R1	2.46	2.21	1.99	1.99	2.09	1.53
R2	2.43	-	-	1.90	-	-
R3	-	2.40	2.40	-	2.05	1.97

*Each number is the mean of two determinations except where indicated by *.

at S7 (1.42 and S1 (1.46) in 1980, and S9 (1.47) in 1979. The highest values for diversity were found in 1978 at S5 and S9 where values of 3.048 and 3.173 were obtained.

In Stotts Creek, only sites S1 and S5 supported fish populations whose trophic structure was balanced in favor of piscivores and insectivores (P+I = 60-75%). At the three remaining sites herbivores, omnivores, and detritivores combined for at least 50% of the biomass. At site S7 in 1980 80% of the biomass came from these trophic classifications.

CLUSTER ANALYSIS

The cluster analyses provide another view of the different communities (Figures 2, 3, 4, and 5). High values of the coefficient of cophenetic correlation for the 1978 and 1980 clusters and the entire series of collections are indicative of good clusters with little distortion. The lower value obtained for the 1979 data probably is the result of population disruption by a flood which occurred between the first and second series of estimates.

All clusters demonstrate that the closest similarities exist between the two determinations at the same collecting station, even during 1979 when the flood occurred. The fish

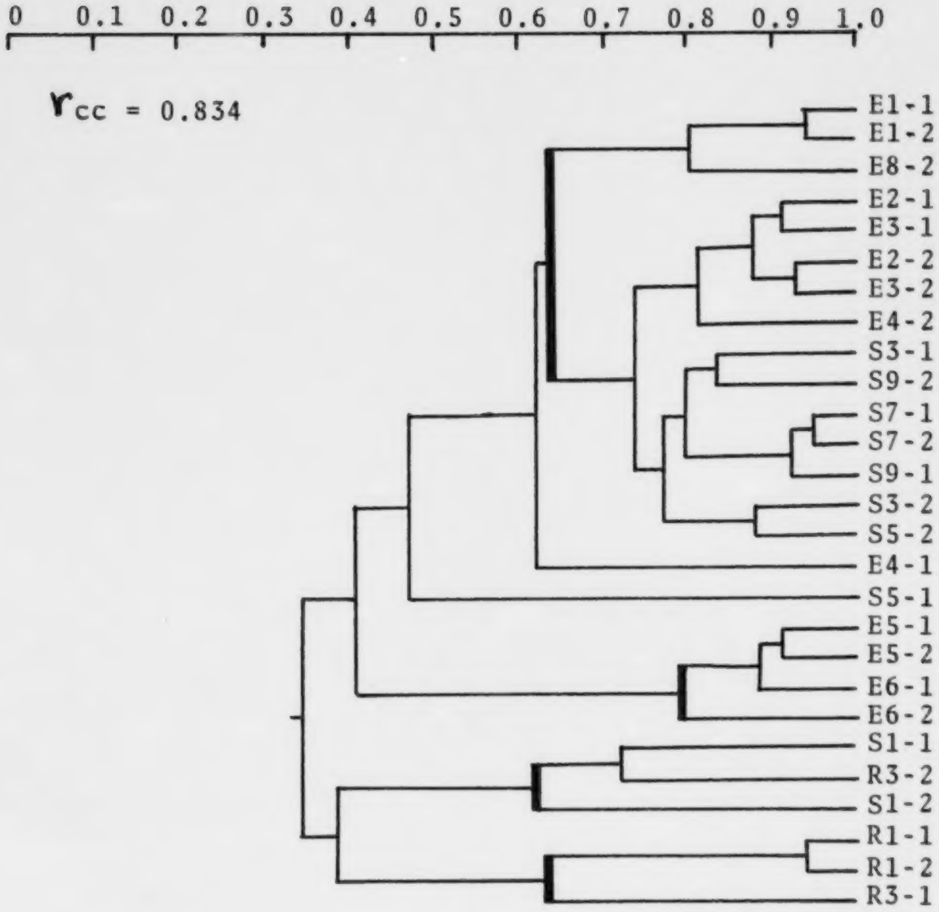

Figure 2: Cluster analysis of 14 fish communities in Rattlesnake (R), Stotts (S), and Eagle (E) Creeks in 1978. Each site was sampled twice during summer.

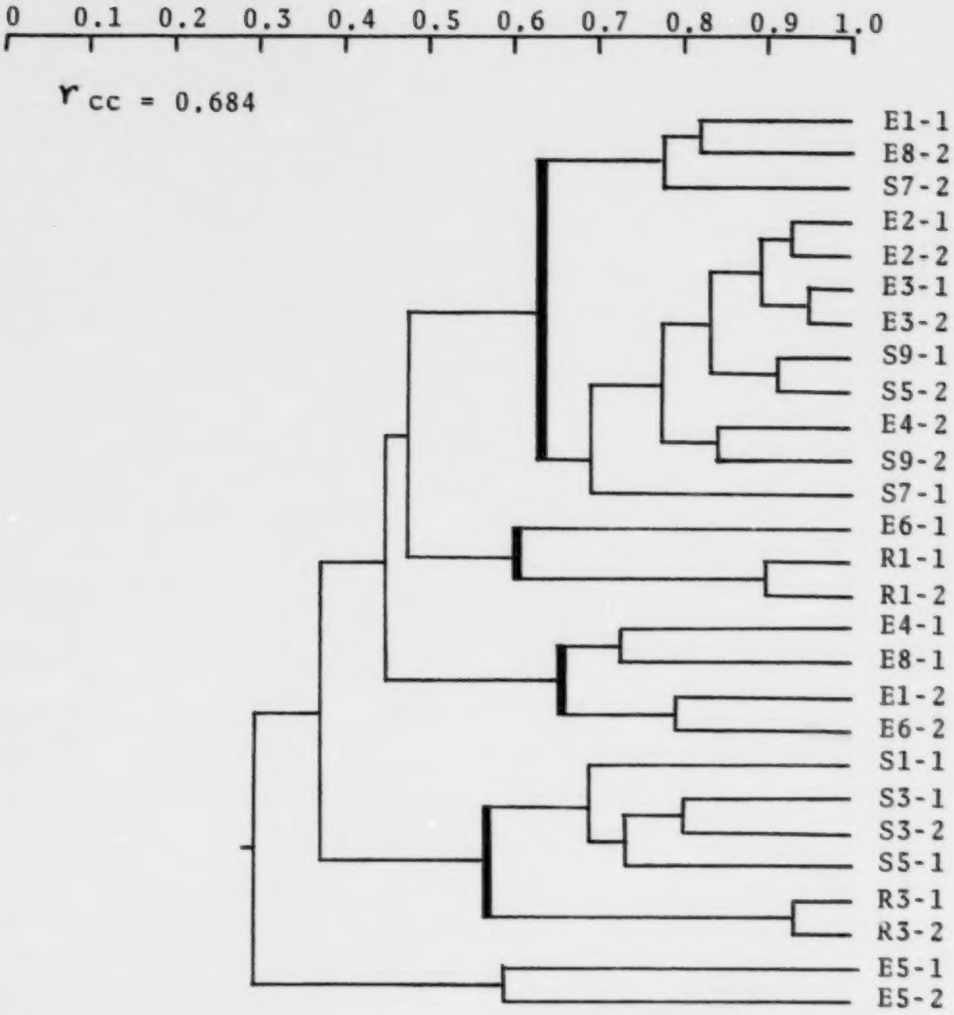

Figure 3: Cluster analysis of 14 fish communities in Rattlesnake (R), Stotts (S), and Eagle (E) Creeks in 1979.

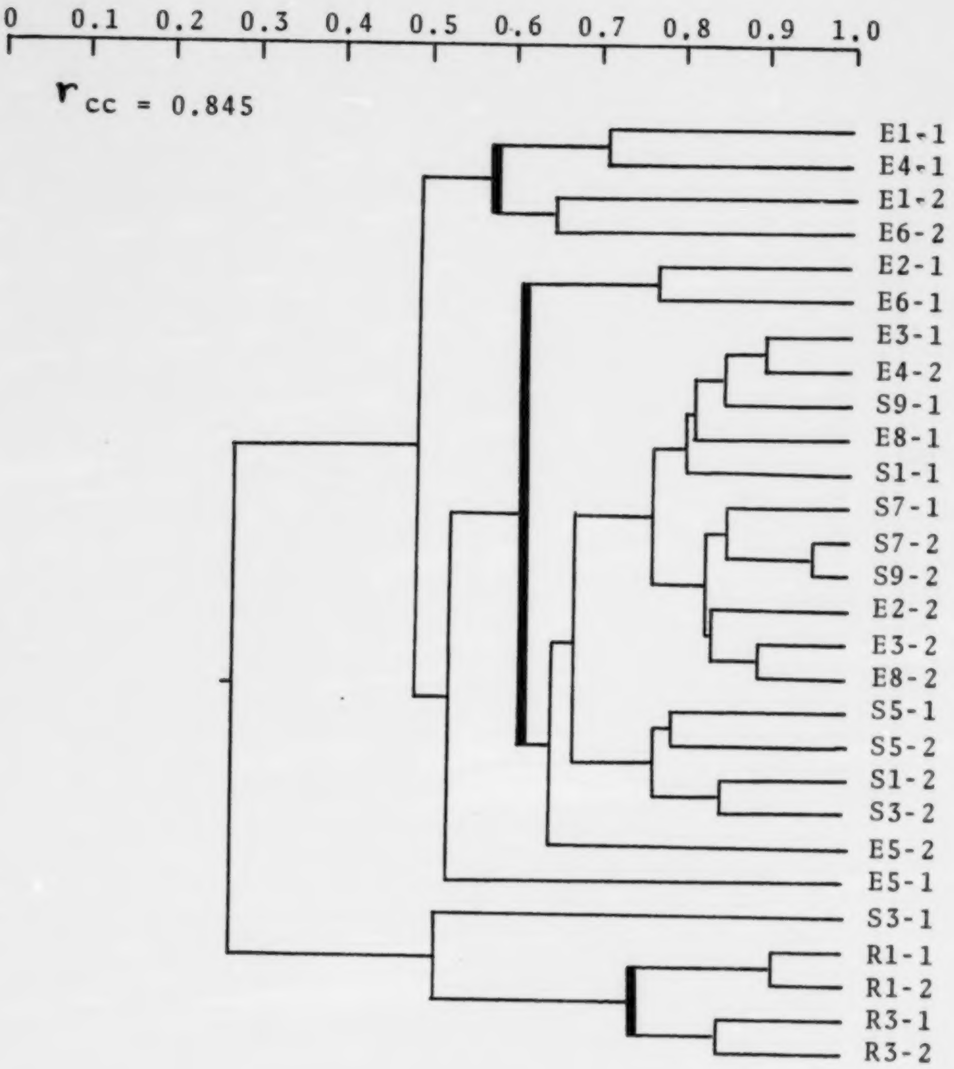
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
r cc = 0.845
E1-1
E4-1
E1-2
E6-2
E2-1
E6-1
E3-1
E4-2
S9-1
E8-1
S1-1
S7-1
S7-2
S9-2
E2-2
E3-2
E8-2
S5-1
S5-2
S1-2
S3-2
E5-2
E5-1
S3-1
R1-1
R1-2
R3-1
R3-2

Figure 4: Cluster analysis of 14 fish communities in Rattlesnake (R), Stotts (S), and Eagle (E) Creeks in 1980.

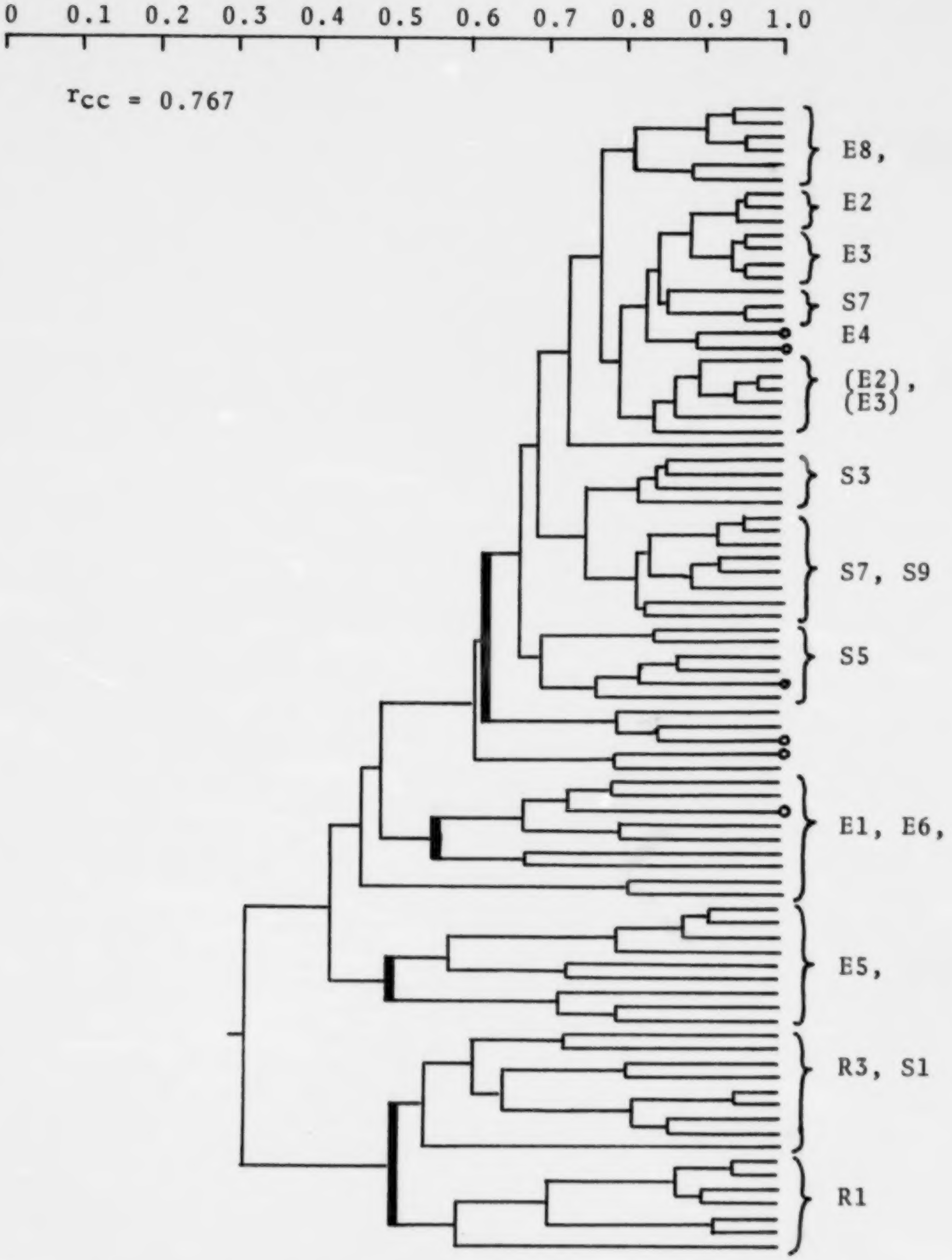

Figure 5: Cluster analysis of fish communities of Rattlesnake (R), Stotts (S), and Eagle (E) Creeks. ○ indicates E4.

communities in Rattlesnake Creek are least similar to those in the other streams, although half of the samples taken at S1, on lower Stotts Creek, were quite similar to those from R3. Among the remaining stations, E5 was most closely related to the Rattlesnake Creek stations, although E1 and E6, which contained similar communities, were somewhat similar to the community at E5. Both of these sites are on smaller streams.

The fish community at E4, downstream from the landfill, tended to be highly variable in its composition, clustering with one group on one occasion and another on another. It tended to be generally different than the one at E8 a short distance upstream.

The more detailed cluster analyses grouped the fish communities in a manner very much like the trophic analysis. Figure 6 depicts the standing crop in relationship to the percentage of piscivores and insectivores in each community. Of all the analyses performed on the data, this appears to best demonstrate basic differences between the fish communities, and probably also provides the simplest and most accurate portrait of the sequence of changes which may be expected when a watershed is developed agriculturally.

Two major groups of fish communities occur, one dominated by piscivores and insectivores and the other dominated by omnivores, herbivores, and detritivores. The standing crops among both groups varied considerably from as little as 40 kg/ha to 300 kg/ha. All but one station remained in its particular group over the three-year period, perhaps indicating that S5 is a fish community which stands on the brink of transition.

MACROINVERTEBRATES

Macroinvertebrate population features presented here include: (1) comparisons of families collected at the sampling stations; (2) the monthly relative abundance of major insect families at each sampling station and month; (3) the diversity indices for each sampling station calculated from the density of each insect family collected; (4) the overall relative abundance for all the macroinvertebrates collected from each of the three study watersheds (Appendix C). Conclusions derived from these are presented as part of the discussion of this study. A more detailed breakdown may be found in Schiappa (1981).

Overall Relative Abundances of Major Macroinvertebrate Groups

Generally, the three watersheds had a similar macroinvertebrate make-up. Over 90% of all the organisms collected were members of Phylum Arthropoda. The insects made up the bulk of the arthropods and in each watershed they also constituted over 90% of the macroinvertebrates. The Diptera were represented by

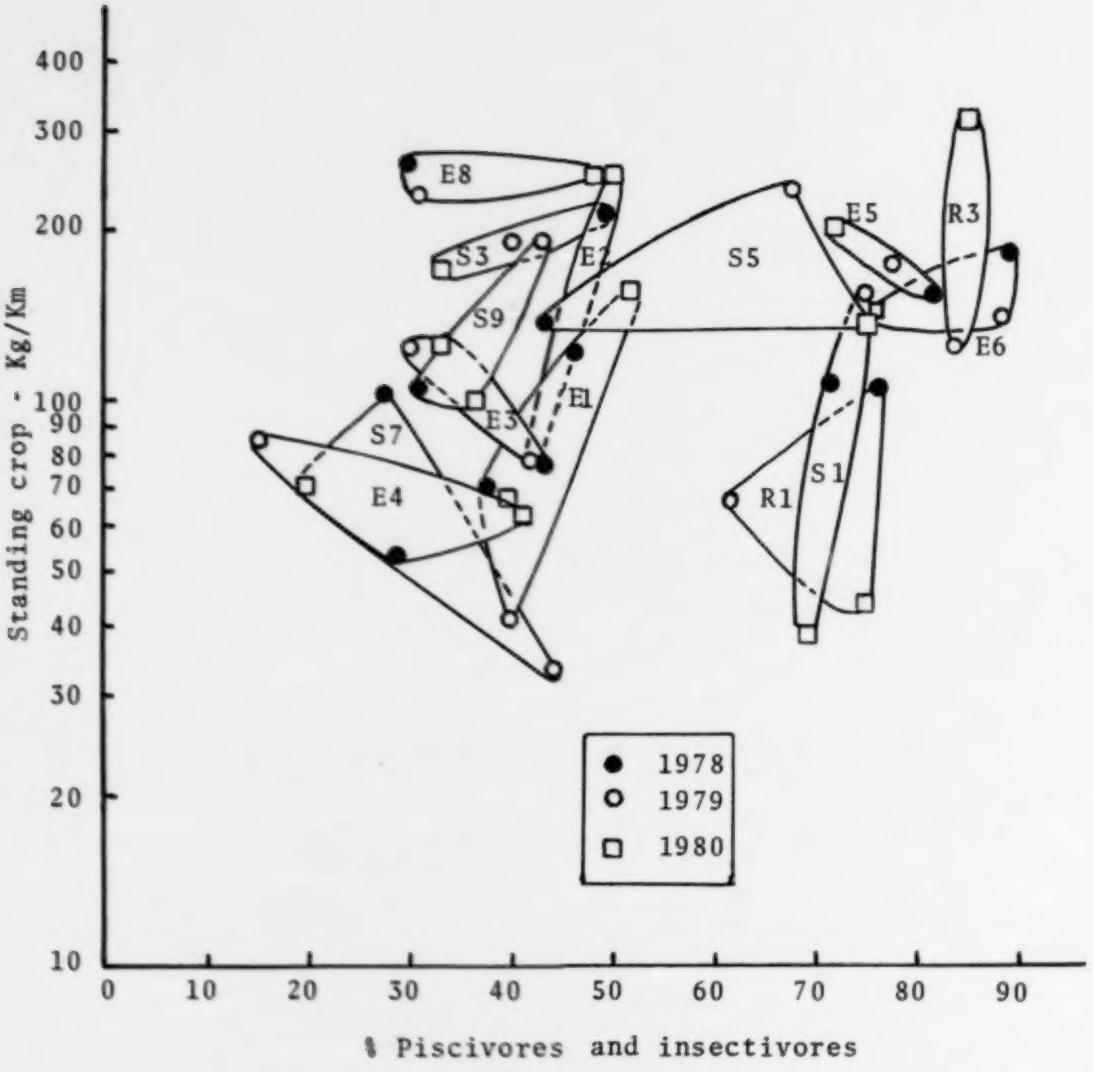

Figure 6 : Standing crop and proportion of piscivores and insectivores of study segments. Each point is a mean of two determinations.

the largest number of individuals, with the relative abundance ranging from 37% at the Stotts Creek watershed to over 50% at Rattlesnake Creek. Chironomidae was not only the predominant dipteran family, but it also represented the largest percentage of individuals of all families collected during the study, consistently ranging from 29% to 30% of the total.

The Annelida followed in density, but the percentages in each watershed were only about 5% or less. The bulk of all annelids were of the class Oligochaeta. Nematoda was usually the next most common phylum. The relative abundance ranged from approximately 1% at the Eagle Creek and Stotts Creek watersheds to slightly above 2% at Rattlesnake Creek.

Mollusca was next in order of abundance. Even at the Eagle Creek watershed where the number of molluscs was the highest, the composition never exceeded 2% of all macroinvertebrates. In the Eagle Creek watershed, Pelecypoda made up most of the molluscs, while at Stotts and Rattlesnake Creeks, the gastropods represented the largest percentage.

Members of other phyla collected included Porifera, Coelenterata, and Platyhelmenthes. In terms of taxonomic similarities above the family level the three watershed streams were similar. There were, however, noticeable differences when relative abundances of some families of gastropods and insects were examined. Table 11 lists the insect and gastropod families that were absent from any one of the watersheds but still occurred somewhere in the study areas. These figures are also interesting because the chance of an occurrence at Rattlesnake Creek is based on only 71 samples while at Stotts and Eagle Creek watersheds the occurrences were based on 262 and 293 collections, respectively.

The most striking difference is the number of Corydalids (Neuroptera) collected exclusively from Rattlesnake Creek (Table 6). Another consistent difference is that Rattlesnake Creek contained few of the dipteran families found at the other watersheds. The Stotts Creek watershed accommodated most of these dipteran families. Many trichopteran families found in Rattlesnake Creek were, however, absent from the Stotts Creek watershed. The number of families from the Eagle Creek watershed fell somewhere between the other two.

Family Comparisons

The Surber samples included a variety of macroinvertebrate families which were compared for each sampling station (Appendix C). Not all of the families collected are shown because some representatives occurred too infrequently to provide substantial comparisons (e.g. those collected at only one station). In all, 74 families are included.

Table 6: Qualitative differences between major families collected from the three study watersheds.

Families not collected from Rattlesnake Creek Watershed		Families not collected from Eagle Creek Watershed		Families not collected from Stotts Creek Watershed	
Gastropoda					
Planorbidae	E-27*	Pleuroceridae	R-4	Pleuroceridae	R-4
		Hydrobiidae	R-16	Hydrobiidae	R-16
				Planorbidae	E-27
Ephemeroptera					
Potamanthidae	S-1	Potamanthidae	S-1	Tricorythidae	E-6, R-1
Leptophebiidae	S-1, E-8			Ephemeridae	R-6
				Baetiscidae	R-4, E-1
				Epherellidae	R-3, E-35
Plecoptera					
Perlodidae	E-9	Nemouridae	R-1, S-1	Perlodidae	E-9
				Chloroperlidae	R-1
Neuroptera					
Sisyridae	E-1	Corydalidae	R-113	Sisyridae	E-1
				Corydalidae	R-113
Trichoptera					
None		Limnephilidae	R-8	Limnephilidae	R-8
		Phryganeidae	R-6, S-3	Rhyacophilidae	R-45, E-5
		Glossosomatidae	R-11	Glossosomatidae	R-11
				Helicopsychidae	E-9, R-2
Diptera					
Dixidae	S-16	Rhagionidae	S-2	Ephyridae	E-4
Chaoborridae	S-15, E-1	Dolichopodidae	S-3		
Psychodidae	S-4, E-8	Dixidae	S-16		
Stratiomyidae	S-1, E-8				
Rhagionidae	S-2				
Dolichopodidae	S-3				

*In each instance, the letter (E for example) refers to the first letter of the watershed where the individuals were collected. The number immediately following the colon (27 for example) refers to the number of individuals collected at that watershed.

Six families were collected regularly at every sampling station by both types of sampling methods. These taxa include the crayfish (Astacidae), two mayfly families (Baetidae and Heptageniidae), two dipteran families (Chironomidae and Simuliidae), one beetle family (Elmidae), and a caddisfly family (Hydropsychidae). Members of three other families which were collected by the Surber sampler at every station included the mayfly family Caenidae and two dipteran families, Ceratopogonidae and Empididae. The net samples contained representatives from numerous families collected at every sampling station. These include members of the snail family Physidae, dragonfly and damselfly families Aeshnidae and Calopterygidae, respectively, a beetle family (Dryopidae), and water striders (Gerridae).

The total number of families included for each station given after the last family on the last page of Table 6. Sites E5 and R2 had the greatest number of families (53 each) when combined samples were considered. E6 and R2 yielded the greatest number of families (41 each) when just the Surbers are taken into account. S3 contributed the greatest number of families (46) collected with the net.

The least number of families (34) was collected from the Eagle Creek watershed at E4. S1 had the least number of families collected from the Stotts Creek watershed (35), while E4 had the fewest families (31) collected with the Surber and S2 had the least number of families (29) collected with the net.

Both Rattlesnake Creek sampling stations had a relatively large number of families collected. The sampling stations having a total number of families greater than the mean number of families were R1, R2, E3, E5, E6, E7, S5, and S8. Sampling stations having a total number of families less than the mean number of families were E1, E2, E4, E8, S1, S2, S3, and S9.

The relative abundance of major insect families is presented in Figures 7-11 for the Eagle Creek watershed, Figures 12-16 for the Stotts Creek watershed, and Figures 17-18 for Rattlesnake Creek. Each figure represents all of the sampling stations in a watershed for one of the five months of the sampling season. Each sampling station in the figures for Eagle and Stotts Creek watersheds is represented by three bars, each of which represents the combined Surber samples for that year. Figures such as these allow for comparisons between sampling stations for any of the months sampled.

The Rattlesnake Creek relative abundance (Figures 17-18) differs somewhat from the Eagle Creek and Stotts Creek values. Since there are only two sampling stations, each is represented by a separate figure. The graphs in this format allow for easy comparison of seasonal data and provide some idea of the life cycles of the animals.

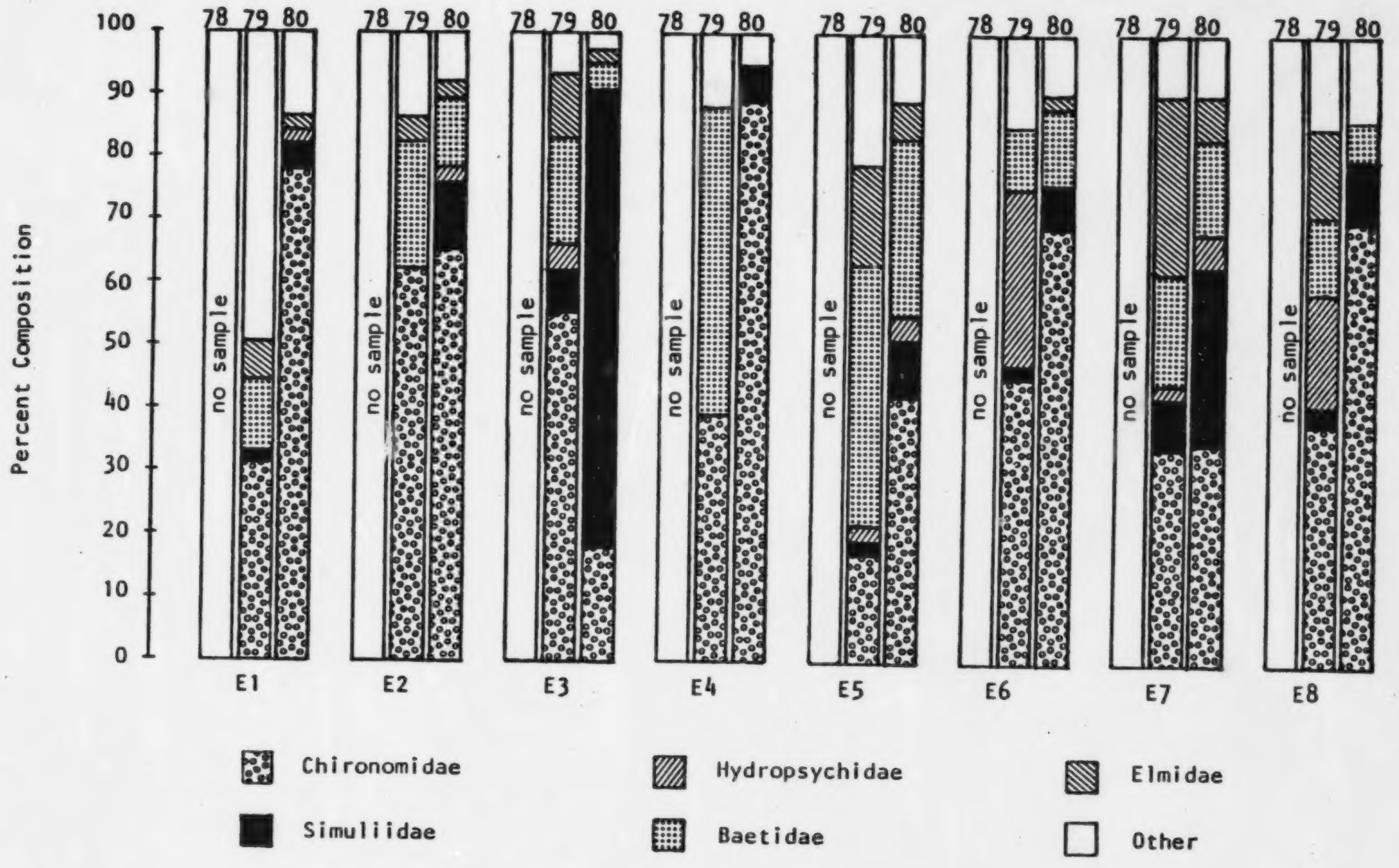

Figure 7: May - Relative abundance of major insect families (Eagle Surber collections).

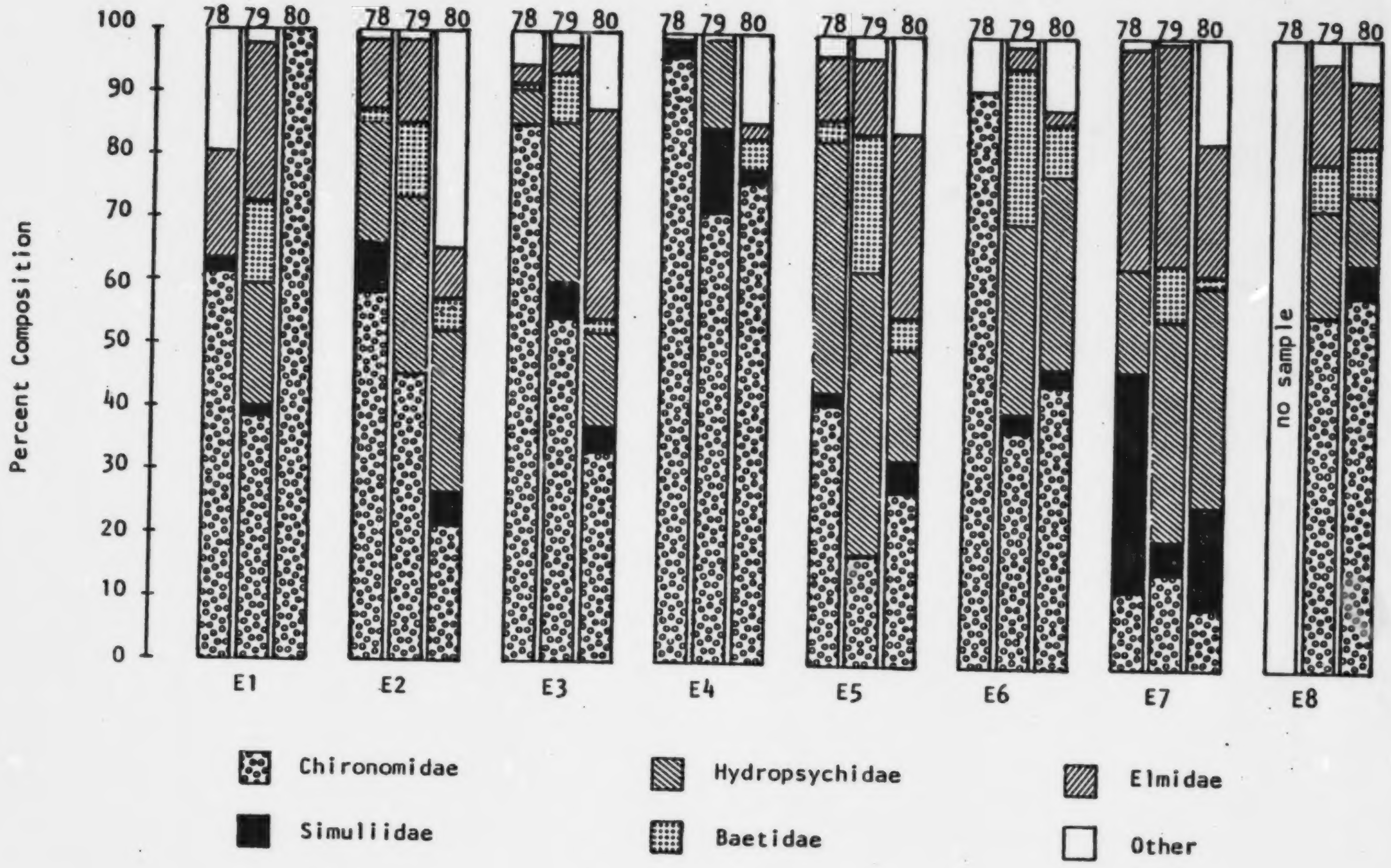

Figure 8: June - Relative abundance of major insect families (Eagle Surber collections).

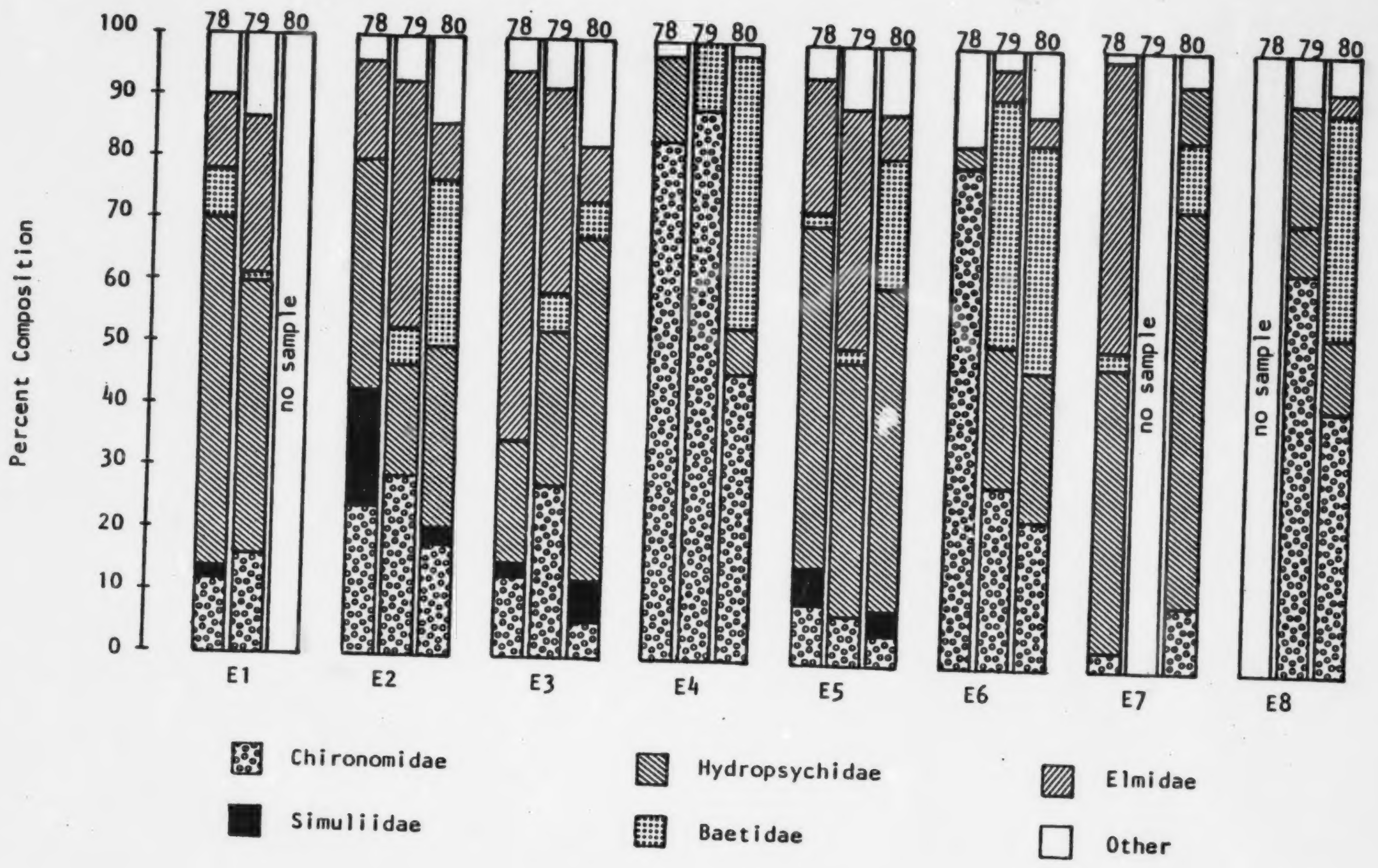

Figure 9: July - Relative abundance of major insect families (Eagle Surber collections).

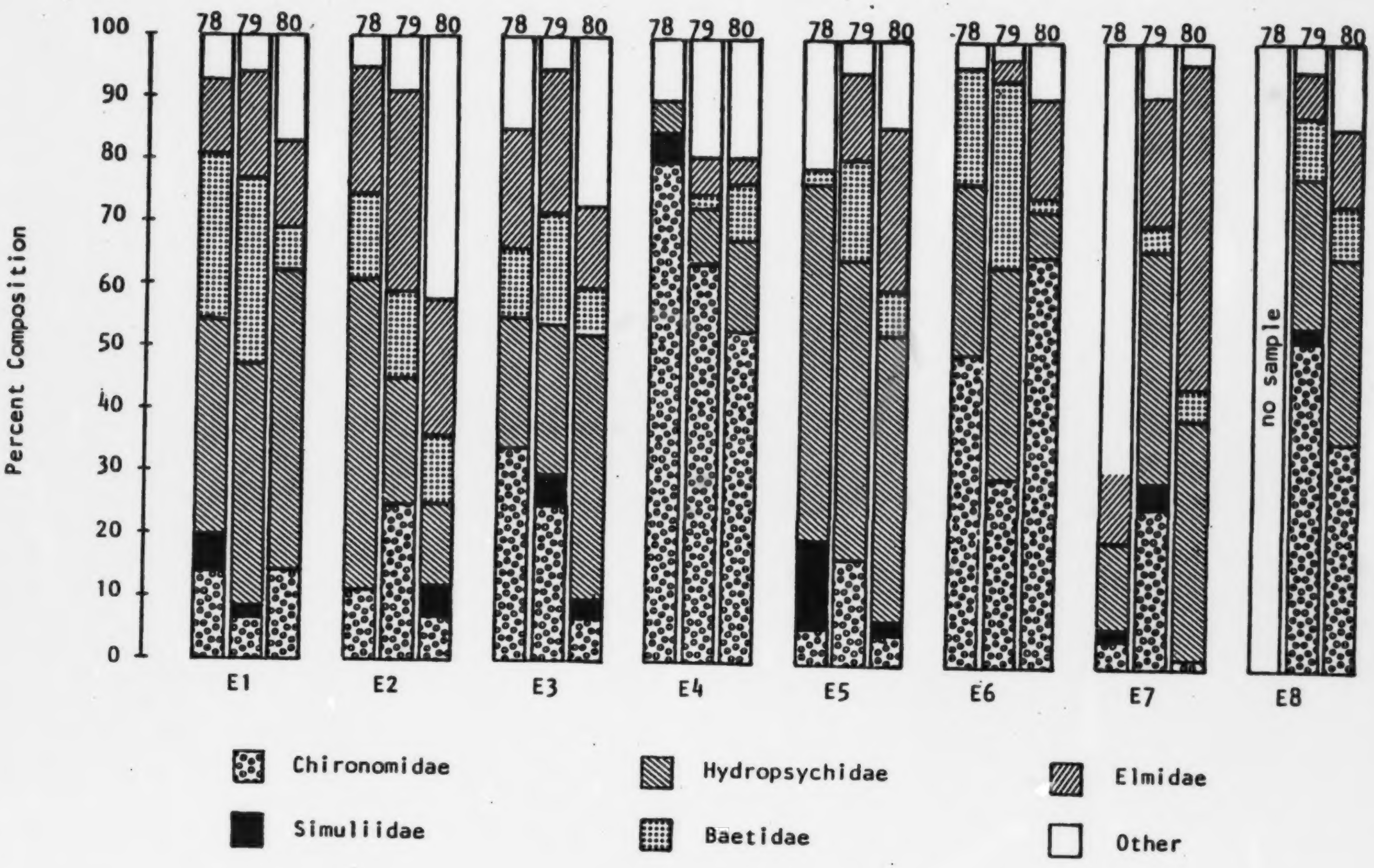

Figure 10: August - Relative abundance of major insect families (Eagle Surber collections).

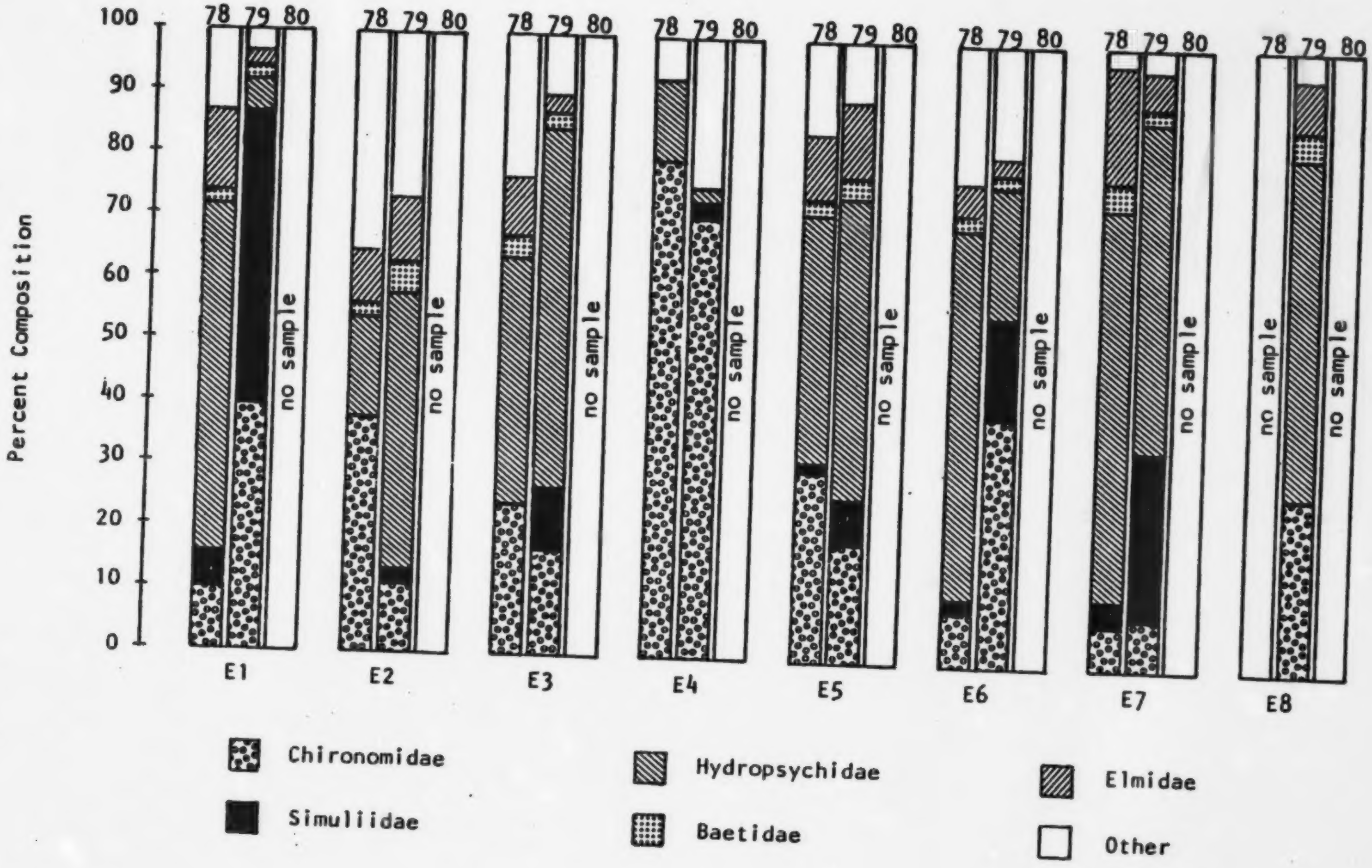

Figure 11: October - Relative abundance of major insect families (Eagle Surber collections).

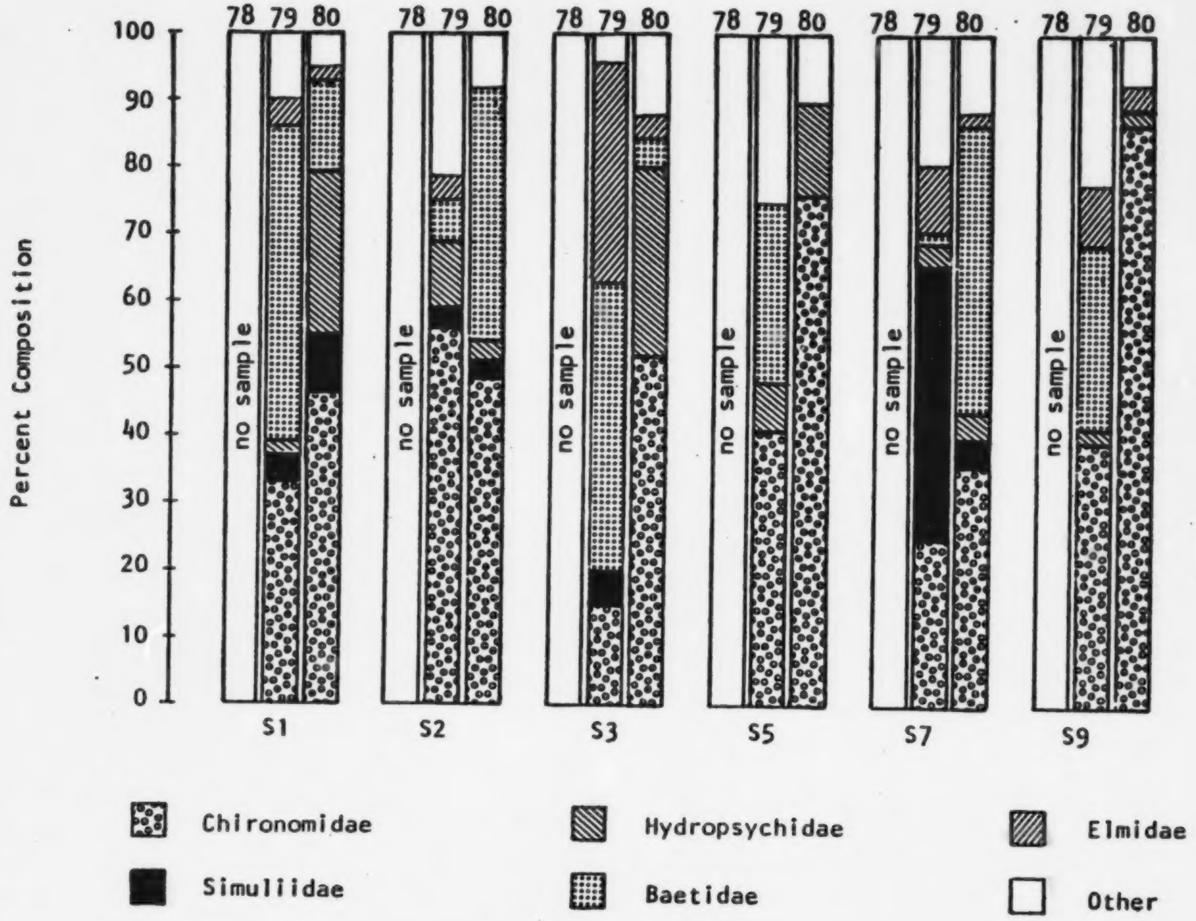

Figure 12: May - Relative abundance of major insect families (Stotts Surber collections).

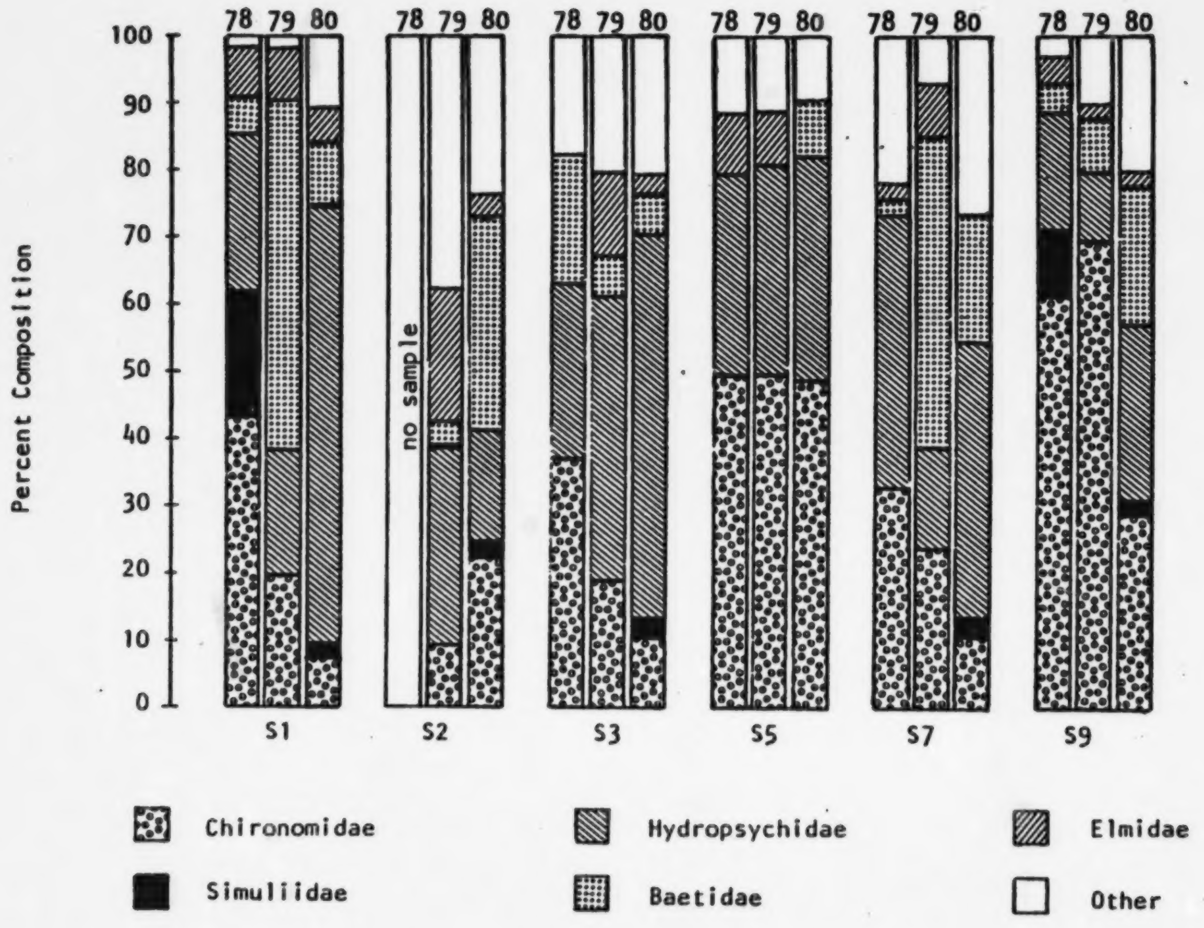

Figure 13: June - Relative abundance of major insect families (Stotts Surber collections).

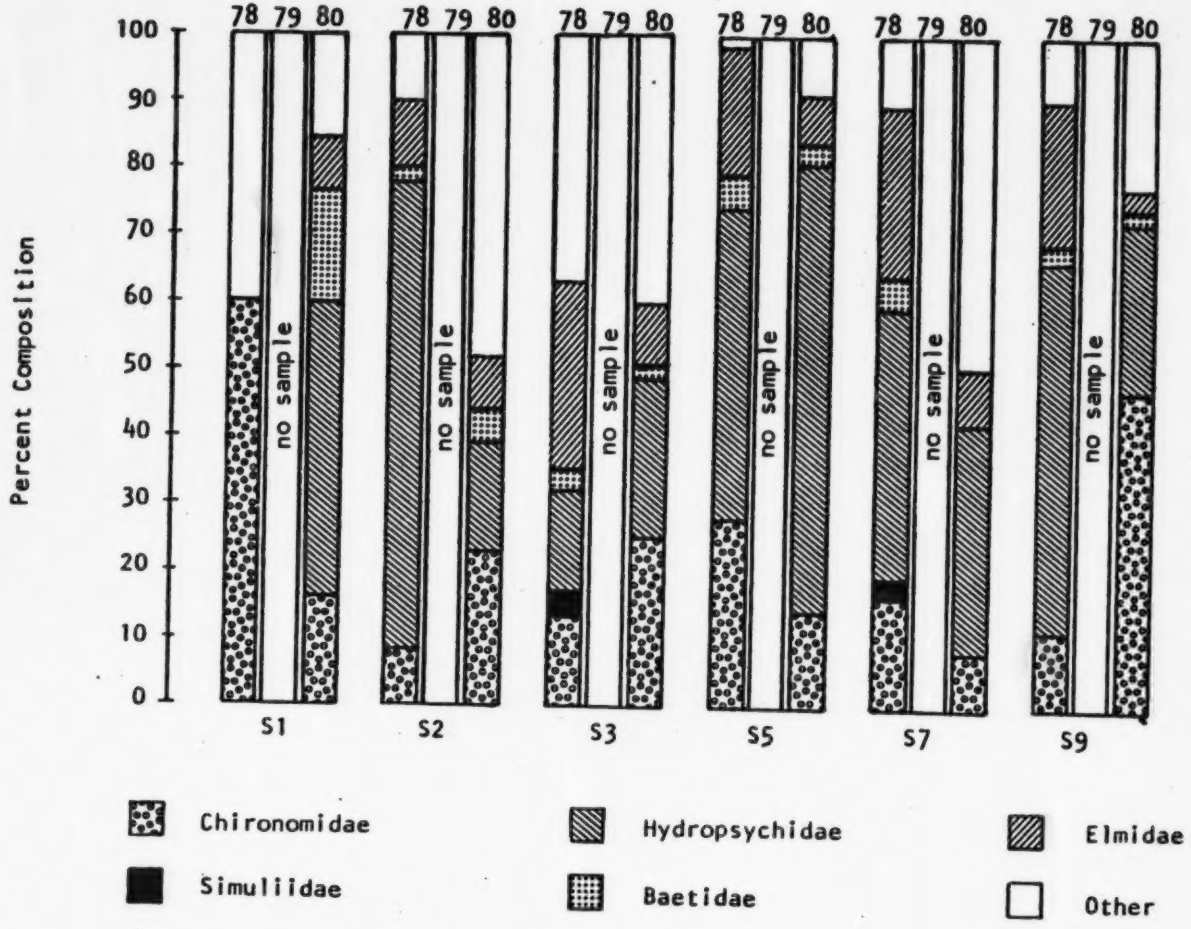

Figure 14: July - Relative abundance of major insect families (Stotts Surber collections).

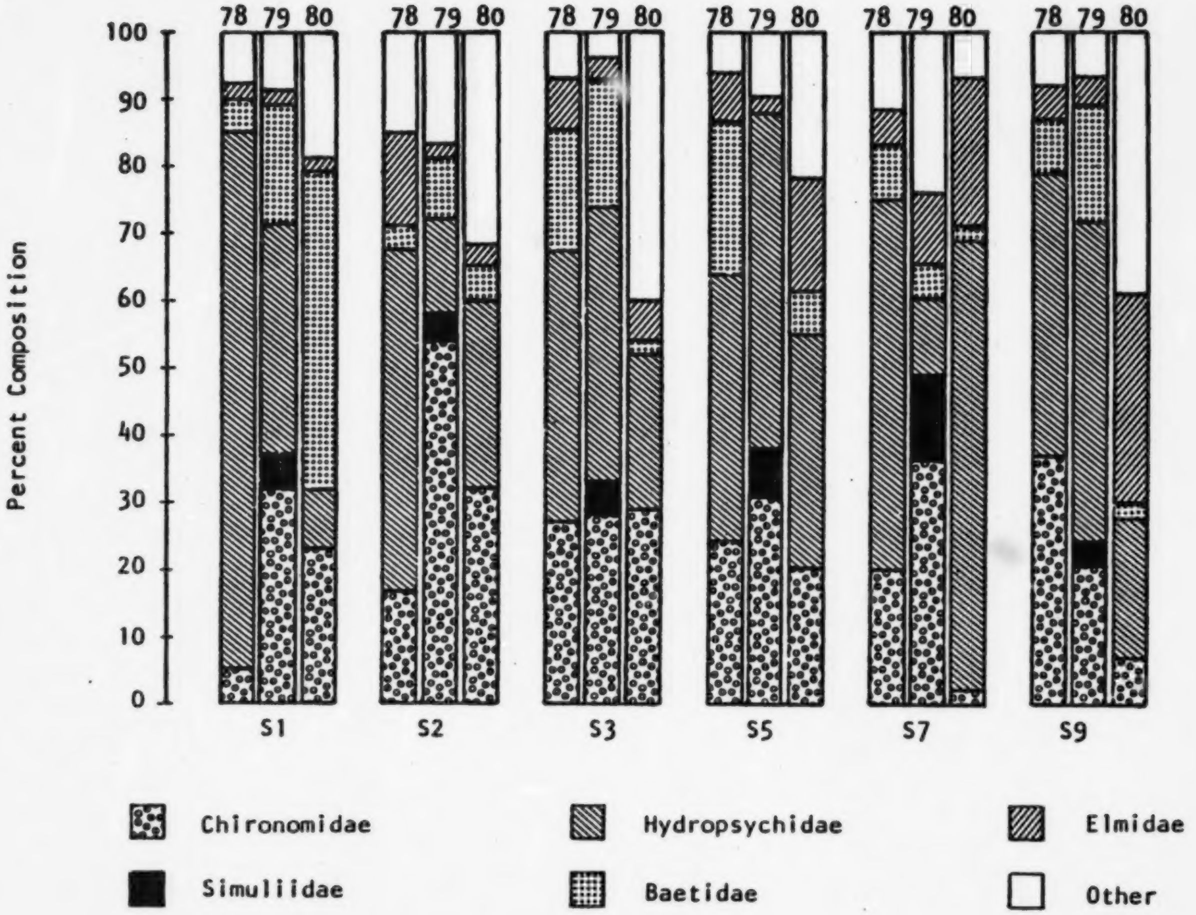

Figure 15: August - Relative abundance of major insect families (Stotts Surber collections).

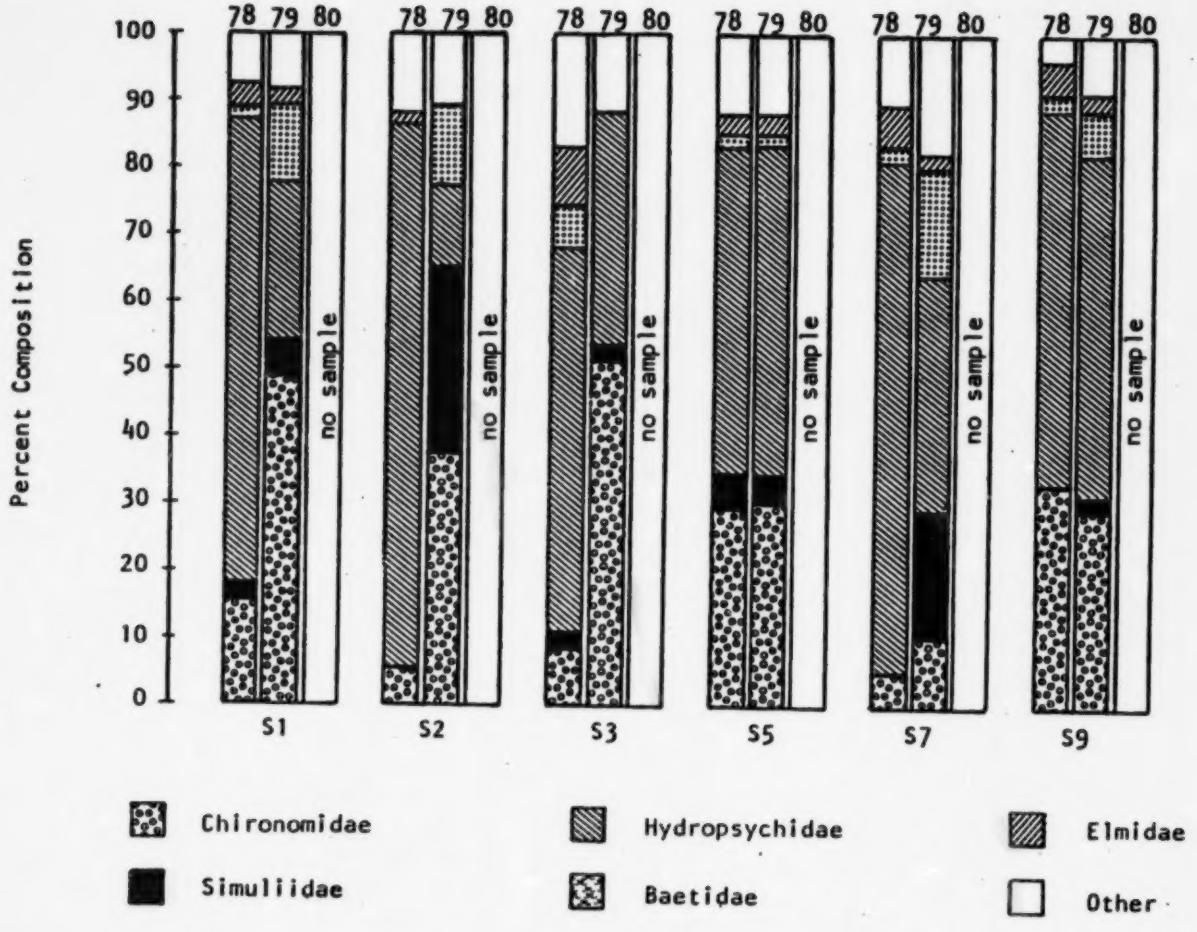

Figure 16: October - Relative abundance of major insect families (Stotts Surber collections).

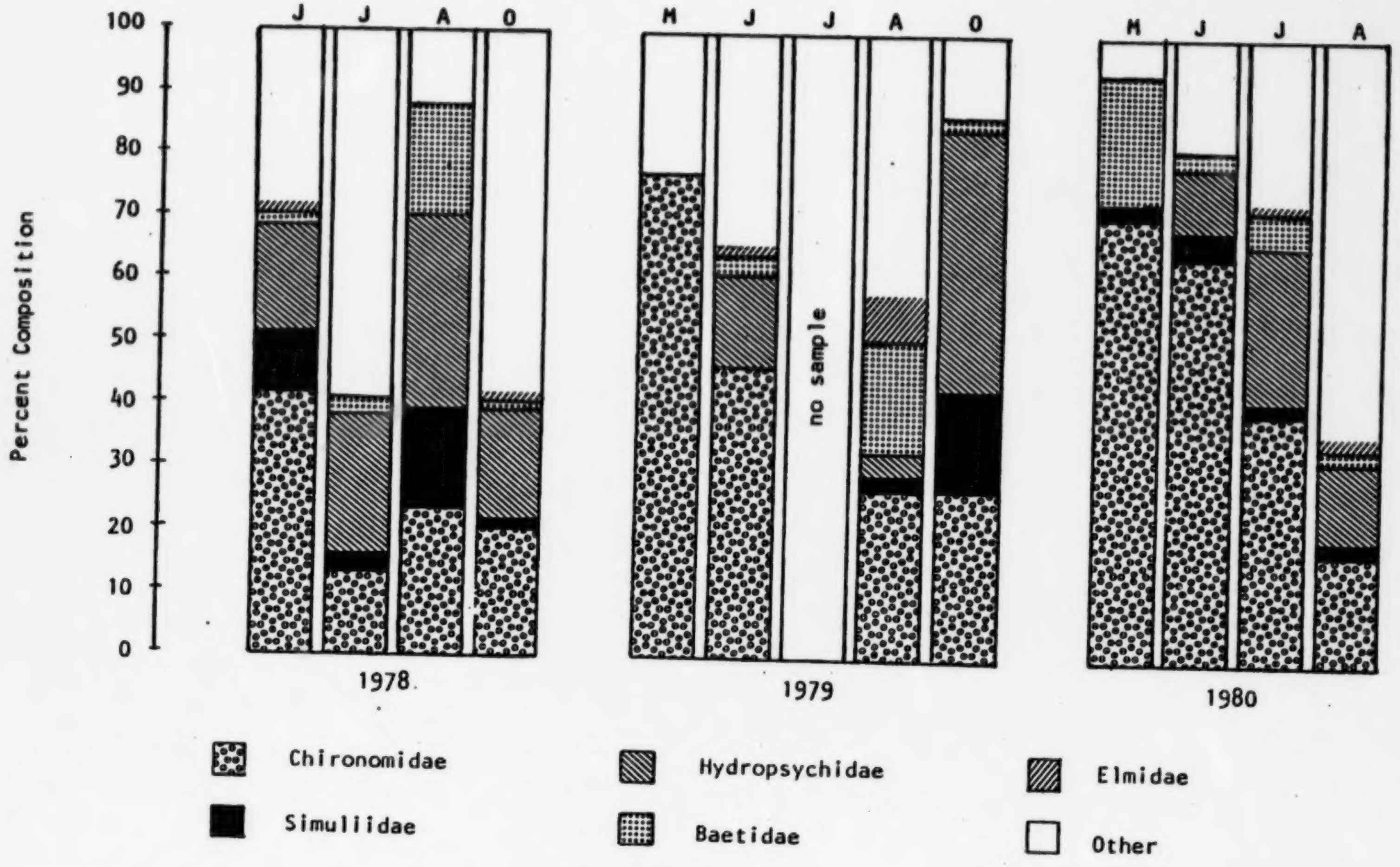

Figure 17: R1 - Relative abundance of major insect families (Rattlesnake Surber collections).

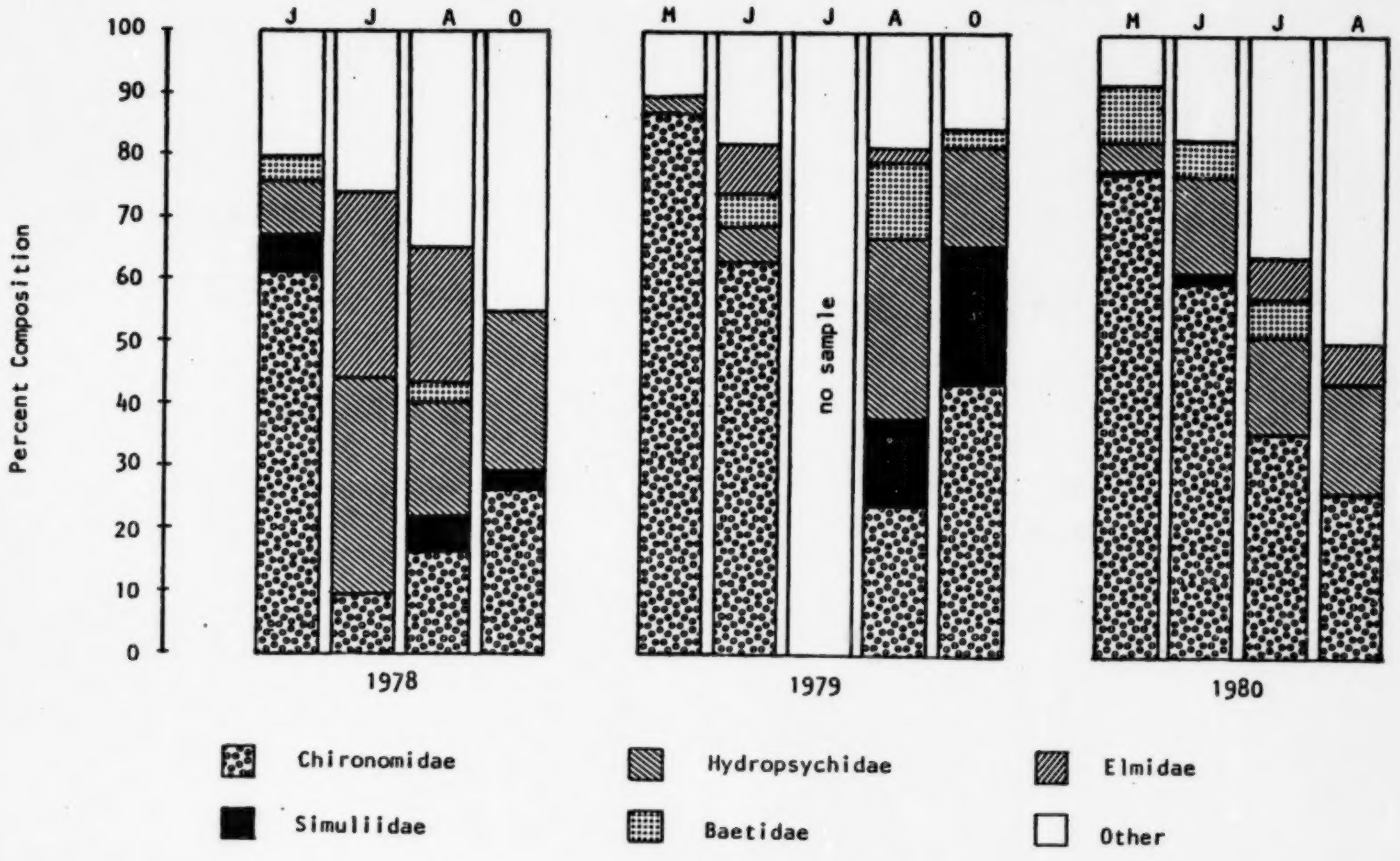

Figure 18: R2 - Relative abundance of major insect families (Rattlesnake Surber collections).

Diversity Indices

The diversity of a community depends on two things: the number of species and the evenness with which the individuals are apportioned among them (Pielou 1975). Each month the total number of individuals of each insect family was calculated by combining the three combined Surber samples. Immatures and adults were included in the totals. The diversity indices were calculated using the density of individuals for families (Tables 7 and 8).

A sample containing many families of great densitites would have a high diversity index. For example, a high diversity at S5 was found in October 1978 (Table 8). If the percentages of individuals in each family are low and even, the result is also a high diversity value. Any combination of samples which does not result in uniform densities will usually result in a low diversity value.

STREAM MORPHOLOGY, HABITAT, AND STREAMBANK VEGETATIONAL PATTERNS

Within a geographic region there tends to be consistency in the dimensions of stream channels in watersheds of similar size (Dunne and Leopold 1978, Crickmay 1974). Most of the tributaries examined were from 25 to 75 km^2 in drainage basin area (Table 1), and might be expected to have quite similar channel dimensions if land use throughout the basins was equitable. Any alterations of the protective vegetal cover on the land of the basin may change the time and volume characteristics of the stream causing the channel to adjust accordingly. It has been shown that increased sediment input results in aggradation with a resultant increase in width of the channel and decrease in depth (Bovee and Milhous 1978). Reduced sediment loading would reverse this trend.

We explored potential differences among the watersheds by examining mean pool depth in relation to land use and potential erosion. The deepest pool examined from each watershed was assigned a value of 100 and the mean depth of other pools rates as a percentage of this reference depth. The data were then grouped with respect to predominant land use and the presence or absence of different kinds of buffer vegetational communities.

Figure 19 shows the relative effectiveness of the different kinds of riparian buffer in the prevention of erosion. For the three watersheds combined, sites with a riparian buffer were 25% to 28% deeper than those lacking buffer. Pools which were flanked by woods were approximately 50% deeper than pools adjacent to areas of altered land use, either residential areas, pastures (meadows), or cultivated fields. Wherever these latter areas were buffered from the stream by a strip of natural grass or trees the stream tended to be considerably deeper. Wherever woods were separated by some other buffer vegetation the pools tended to be more shallow (Figure 20).

When there was no buffer on either side of a stream, woods was the most effective form of land use (66%). Meadows were next most effective (54%), followed by fields (31%), and residential areas (26%) (Table 9).

Relative mean pool depths of the six streams of Eagle Creek watershed and the seven streams of Stotts Creek watershed are compared to the five study sites of Rattlesnake Creek in Table 16. Fishback Creek in the Eagle Creek watershed and Koots Fork and South Prong in the Stotts Creek watershed compare favorably to the control stream which had a cumulative relative mean pool depth of 61%. Fishback Creek also had a cumulative relative mean pool depth of 61%, and Koots Fork and South Prong had values of 71% and 70%, respectively (Table 10).

Rattlesnake Creek had a buffer strip on at least one side of the five sites studied, as did Koots Fork. For land use other than woods, South Prong had no sites lacking an interface on at least one side, while Fishback Creek lacked a buffer on both sides at only one site.

Table 7: Benthic Insect Diversities based on Families for Eagle Creek Stations.

Month	Year	E1	E2	E3	E4	E5	E6	E7	E8
May	1978	-	-	-	-	-	-	-	-
	1979	1.336	1.160	1.493	0.978	1.690	1.565	1.739	1.688
	1980	0.892	1.258	0.936	0.494	1.682	1.189	1.759	1.211
June	1978	1.159	1.246	0.682	0.192	1.309	0.505	1.381	-
	1979	1.584	1.348	1.330	0.796	1.486	1.392	1.443	1.305
	1980	-	1.690	1.596	1.059	1.752	1.424	1.713	1.404
July	1978	1.312	1.456	1.116	0.539	1.321	0.611	0.937	-
	1979	1.356	1.465	1.515	0.377	1.362	1.366	-	1.069
	1980	-	1.734	1.530	1.004	1.440	1.548	1.241	1.338
August	1978	1.694	1.377	1.690	0.708	1.368	1.218	1.403	-
	1979	1.491	1.576	1.700	1.048	1.457	1.339	1.603	1.515
	1980	1.757	2.159	1.913	1.540	1.742	1.357	1.493	1.763
October	1978	1.483	1.965	1.614	0.646	1.536	1.338	1.123	-
	1979	1.220	1.786	1.474	0.893	1.630	1.785	1.357	1.212
	1980	-	-	-	-	-	-	-	-

Table 8: Benthic Insect Diversities based on Families for Rattlesnake and Stotts Creeks.

Month	Year	R1	R2	S1	S2	S3	S5	S7	S9
May	1978	-	-	-	-	-	-	-	-
	1979	0.718	0.947	1.366	1.610	1.349	1.622	1.579	1.572
	1980	1.000	0.979	1.517	1.236	1.376	0.885	1.455	0.641
June	1978	1.625	1.849	1.456	-	1.451	1.388	1.492	1.327
	1979	1.340	1.635	1.263	1.732	1.715	1.361	1.475	1.159
	1980	1.357	1.394	1.277	1.921	1.363	1.458	1.674	1.647
July	1978	1.616	2.271	0.850	1.086	1.673	1.326	1.622	1.350
	1979	-	-	-	-	-	-	-	-
	1980	2.015	1.857	1.777	1.889	1.971	1.184	1.888	1.687
August	1978	2.174	2.174	0.872	1.327	1.534	1.466	1.399	1.381
	1979	1.908	2.298	1.616	1.539	1.660	1.394	1.934	1.499
	1980	2.346	2.269	1.624	1.665	2.081	1.795	1.469	1.917
October	1978	2.100	2.200	1.106	0.775	1.599	2.040	1.030	1.177
	1979	1.686	1.565	1.725	1.639	0.572	1.446	1.840	1.362
	1980	-	-	-	-	-	-	-	-

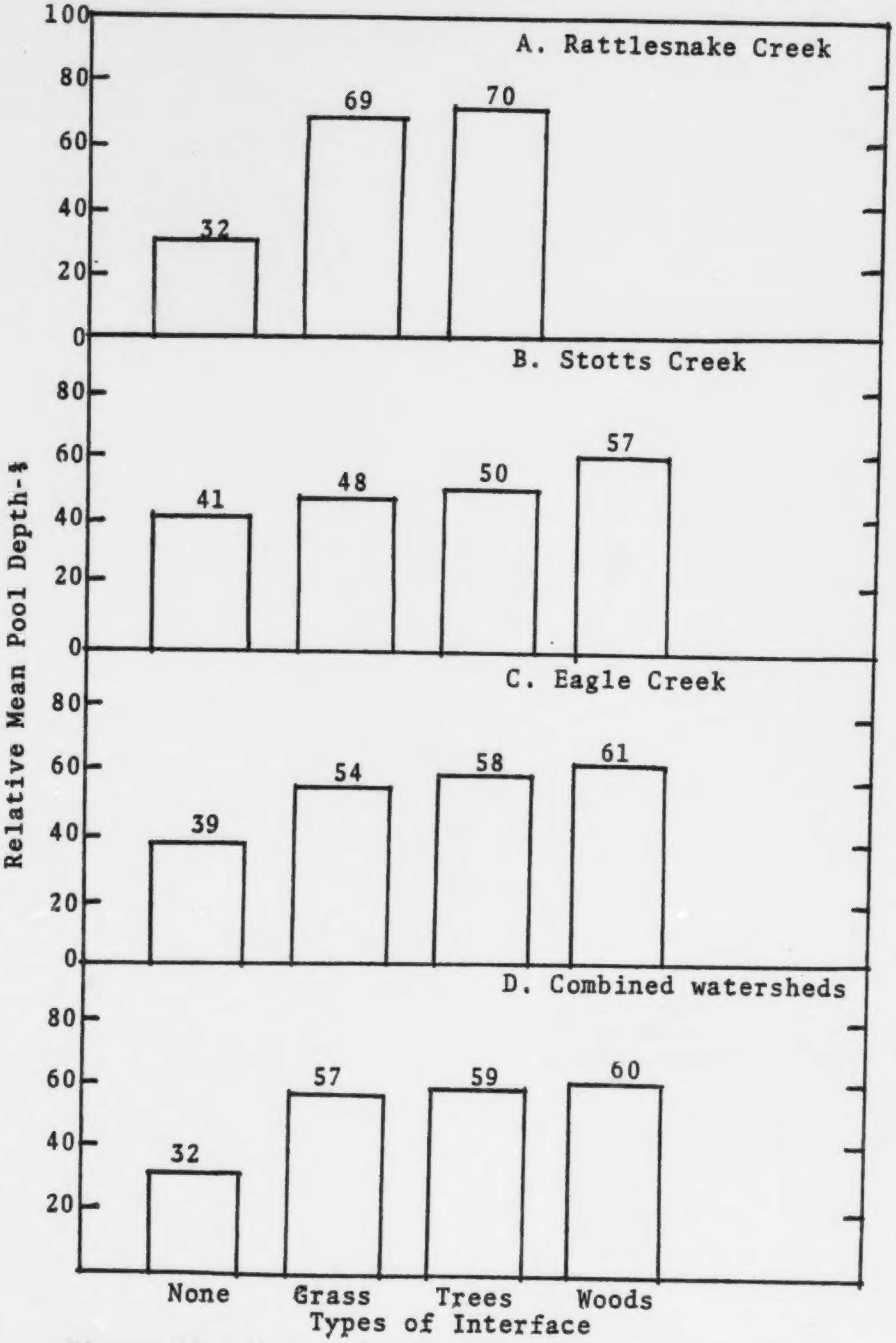

Figure 19 ; Mean relative depth of stream pools in areas of different types of buffer interface.

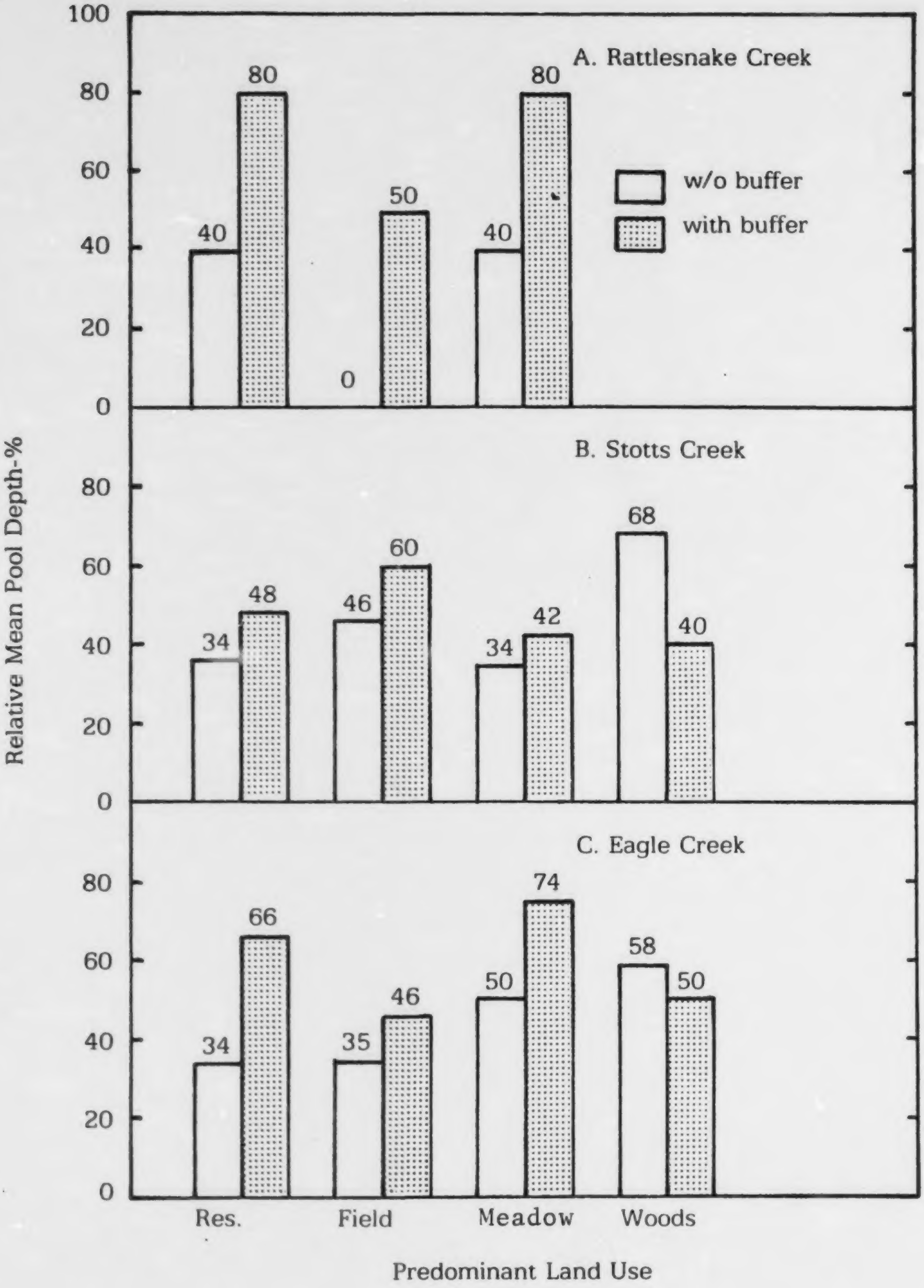

Figure 20: Mean relative depth of stream pools in areas of different land uses, with and without a buffer interface.

Table 9: Comparison of the relative mean pool depths of land use areas along the Eagle Creek, Stotts Creek, and Rattlesnake Creek watersheds that have no interface.

Land Use	Stream	N	Position of land use (side of stream)	Cum. Rel. Mean Pool Depth (%)
Woods	Eagle	6	Both sides	58
	Stotts	6	Both sides	74
	Rattlesnake	0	Both sides	0
				$\bar{x}$ = 66
	Eagle	2	One side	50
	Stotts	0	One side	0
	Rattlesnake	0	One side	0
				$\bar{x}$ = 50
Meadow	Eagle	3	Both sides	54
	Stotts	0	Both sides	0
	Rattlesnake	0	Both sides	0
				$\bar{x}$ = 54
	Eagle	2	One side	37
	Stotts	2	One side	34
	Rattlesnake	0	One side	0
				$\bar{x}$ = 36
Residential	Eagle	1	Both sides	18
	Stotts	1	Both sides	34
	Rattlesnake	0	Both sides	0
				$\bar{x}$ = 26
	Eagle	3	One side	38
	Stotts	3	One side	34
	Rattlesnake	0	One side	0
				$\bar{x}$ = 31
Field	Eagle	3	Both sides	31
	Stotts	0	Both sides	0
	Rattlesnake	0	Both sides	0
				$\bar{x}$ = 31
	Eagle	2	One side	43
	Stotts	1	One side	33
	Rattlesnake	0	One side	0
				$\bar{x}$ = 40

Table 10: Comparison of the cumulative relative mean pool depths of individual streams of the Eagle Creek and Stotts Creek watersheds with the relative mean pool depth of individual sites and the cumulative mean pool depth of Rattlesnake Creek.

Stream Sites	Cumulative Relative Mean Pool Depth (%)
Eagle Creek	
Fishback Creek	61
Upper Eagle Creek	57
Little Eagle Creek	55
Mounts Run	54
Finley Creek	43
School Branch	34
$\bar{x}$	52
Stotts Creek	
Koots Fork	71
South Prong	70
Skunk Hollow	51
Lost Creek	49
Buck Creek	35
North Prong	33
Henderson Creek	28
$\bar{x}$	48
Rattlesnake Creek	
Rattlesnake Creek	62
$\bar{x}$	62

DISCUSSION

The basic objective of the overall research project was to examine the influence of agriculture on water quality and to attempt an improvement of water quality in heavily agriculturalized watersheds by instituting best management practices (BMP). Our role in this multi-institutional endeavor (including Purdue University, Holcombe Research Institute of Butler University, Soil Conservation Service of USDA, and the Indiana Heartlands Coordinating Commission) was to examine the aquatic community in relation to land use and to chart its improvement during a three-year period.

We have not observed a discernible improvement in the fish communities of our study streams. We have obtained data describing the benthic and fish communities as they occur in small streams in both forested and agricultural watersheds over a three-year period. Despite rather drastic differences in weather pattern from year to year the aquatic communities exhibited an unexpected stability in terms of standing crop and composition over the three-year period. This stability might be thought of as reproducibility in that a given station could be expected to maintain its special character over a reasonable period of time because of the particular combination of physical and chemical makeup in that portion of the stream. A basic change in that environment would ultimately lead to changes in the nature of the community. The fish and benthic communities of the study streams provide an excellent indication of the direction of the changes in aquatic communities which occur as land use in the watershed becomes predominantly agricultural.

The biotic response implied by this study is non-linear in that an increment of improvement in water quality, i.e., a reduction in the degree to which a stream is influenced by man, does not necessarily result in an increment of improvement in the aquatic community, i.e., a small degree of movement of the community towards its "natural" state. Rather, the pattern discerned for these stream communities suggests that progressive basic improvements in environmental quality could occur with little or no evidence of benefit to the stream community until a critical level was reached, whereupon a sudden, almost saltatorial transformation would occur (in terms of ecological periods of time).

The species composition and community structure of fauna in Rattlesnake Creek, as well as studies of other nearby streams

(Gerking 1949, Benda and Gammon 1968, Gammon 1970), adequately portray a desirable stream fauna. In small-to medium-sized forested midwestern streams (stream order II to V and watershed area as small as about 20 km^2) the fish community is dominated by golden and black redhorse, hog sucker and rock bass. Stoneroller, creek chub and striped shiner are numerous, but constitute a relatively small percentage of biomass. Bluntnose minnow, the only detritivore of significance in these streams, is present, but not numerous. A large variety of darters and centrarchids is commonly present. The average size of fish is relatively large, as is the diversity as measured by the Shannon index (1.8 to 2.5 when determined by numbers; somewhat lower when weights are used). The standing crop varies widely, even in the same pool over a period of time, but the usual range appears to be from about 50 to perhaps 200 kg/ha.

Grouping various fish species into trophic categories, insectivores comprise the largest component of the community (40%-60%; the smaller the stream the higher the value) and form the greatest number of species. Centrarchids, here considered to be piscivores, form 25-30% of the community biomass and may be joined by other piscivores, especially in larger streams. Herbivores comprose less than 10% of the biomass. Detritivores and omnivores together contribute 10-30%; toward the larger value in small streams because of larger numbers of creek chub.

This description of the fish community in a small, relatively undisturbed stream may not apply to larger, undisturbed streams, nor does it presume to provide a portrait of what the community would be like if man were not an element in the ecological scene. In all probability, the fish community in pre-1800 Rattlesnake Creek may well have been almost totally dominated by piscivores and insectivores, but this is conjectural.

The macroinvertebrate population of Rattlesnake Creek was diverse and contained some groups not found at either Stotts or Eagle Creeks. Collections contained an average of 13 (R1) and 16 (R2) families. Chironomids were prevalent in May, but steadily declined to about 25% of the collection in July and August. Hydropsychidae were uncommon in May, but progressively increased in importance during the summer to about 25%. Several other families of Trichoptera, Ephemeroptera, and Gastropoda were common here, but absent or extremely rare in Stotts and Eagle Creeks. Elmidae, Psephenidae, and Gyrinidae were common. These forms and a variety of others combined to make up about half of the macroinvertebrate population during mid- and late summer. Shannon diversities based on numbers in families were generally less than 1.0 in May, 1.3 to 1.9 in June, and more than 2.0 from July to October.

The two agricultural watersheds have some streams which appear to approach the model community, but most streams depart substantially from it. Four of the five collecting stations in Stotts Creek are known to have been significantly influenced sometime during the course of the study by agricultural point sources of pollution, namely, animal feed lots. Bulldozing the bank and even the stream itself was observed at two sites during late 1978, but these local influences seem not to have disturbed the communities for very long. In order to assess the non-point detrimental contribution to environmental quality of the streams these point-source influences need to be evaluated. It is obvious that in Stotts Creek the agricultural point-sources are responsible for influencing the fish community detrimentally to a considerable degree.

Despite periodic point-source influences and the overall agricultural NPS contributions, two of the sampling stations (S1 and S5) contained fish communities which somewhat approached that of the model community. S5 contained more herbivorous stonerollers and fewer omnivores than the model community, but was well-balanced otherwise. S1, on the mainstem of Stotts Creek, was too large to be adequately sampled by the electric seine and was certainly influenced by upstream point-source problems, yet it appeared to contain an appropriate insectivore component and a somewhat reduced piscivore component. This lower portion of Stotts Creek probably could support a very good fishery, as evidenced by the capture of a 5 pound smallmouth bass in one collection. Both S1 and S5 harboured good bass populations (12-15% of the standing crop).

The remaining stations were strongly and negatively influenced. Two of the six population estimates at S7 were influenced by recent fish-kills and contained extremely low standing crops, but the composition was similar to other S-stations which were impacted to a somewhat lesser extent. Piscivores were very scarce at all three stations and comprised less than 10% of the standing crop; bass alone constituted less than 5%. Insectivores were also reduced, but not quite as drastically. Herbivores, primarily stonerollers, comprised 15-30% of the standing crop and detritivores and omnivores together contributed 35-40%.

The macroinvertebrate populations of Stotts Creek were fairly similar at all stations, although S3 and S7 usually yielded more families than the other sites. Chironomidae were more common at both upstream sites (S5 and S9) during spring, but declined after June to 25% or less in comparison with populations at other S-sites. Mean diversities were very similar for all stations, ranging from about 1.4 to 1.6. The lower diversity here is attributable in part to the lack of a variety of families which were important in Rattlesnake Creek. Little seasonal variation in diversity values was noted here. The land cover of the watershed upstream from each sampling station was estimated from LANDSAT data by Hyde, Goldblatt, and Stolz (1982), who also detailed land use for 5 acre blocks. Land use was fairly uniform throughout much of the Stotts Creek watershed (Table 11), with 23%-29% as wooded, rolling hills and 53%-58% cropland (corn and soybeans).

Table 11. Land Cover Estimates for Subwatersheds in Stotts Creek Watershed, as Identified from LANDSAT Data.

		Total Area Acres	Cropland % of Total	Forest % of Total	Remaining Area* % of Total
Stotts	S1	36420	53.4	28	18
North Prong	S3	13360	55.0	26	19
Upper N. Prong	S5	6930	57.7	23	19
South Prong	S7	20285	52.7	29	18
Upper S. Prong	S9	13755	58.1	24	18

* Remaining area was classified as (1) water, (2) water saturated land, (3) buildings and associated lots, or (4) grass-covered areas.

Table 12. Land Cover Estimates for Subwatersheds in Eagle Creek Watershed, as Identified from LANDSAT Data.

		Total Area Acres	Cropland % of Total	Forest % of Total	Remaining Area* % of Total
School Branch	E1	5120	73.6	10	16
Fishback	E2	13510	65.3	17	18
Little Eagle	E3	16535	72.4	13	15
Finley	E4	6460	72.1	11	17
Upper Eagle	E5	18320	68.6	10	21
Mts. Run	E6	10860	59.7	9	31
Upper Finley	E8	4840	74.4	8	18

*Remaining area was classified as (1) water, (2) water saturated land, (3) buildings and associated lots, or (4) grass-covered areas.

Evaluation and interpretation of the fish communities of Eagle Creek streams is somewhat more difficult than for Stotts Creek because of the extensive changes wrought when the Indiana Department of Natural Resources attempted to eradicate all fish from the Eagle Creek watershed in 1966. The results of this activity has been detailed elsewhere (Fisher and Gammon, 1981). Briefly, rotenone was used to kill all fish prior to closing the dam gates for Eagle Creek Reservoir in an effort to eliminate gizzard shad and carp from the watershed. These species were not eliminated, but many others were, including golden redhorse and hog sucker which were listed as first and fourth, respectively, in abundance by weight in a typical pool (McGinty 1966).

Smallmouth bass was the second most dominant species by weight prior to this activity, but subsequently became scarce. Other centrarchids were heavily stocked in an effort to rehabilitate this watershed with some measure of success, but smallmouth bass remain rare despite repeated efforts to reestablish them following detoxification. Perhaps the absence of redhorse and hog sucker is somehow involved; or perhaps the watershed was on the brink of converting from centrarchid dominance to minnow dominance and the rotenoning simply hastened the transformation. The cause is unknown at this time. The trophic analyses, despite the extensive biotic alteration, generally fall into the pattern indicated by the other watershed stations.

Among the individual tributaries, upper Finley Creek contained the largest standing crop of fish (252 kg/ha). It is the most agriculturally developed watershed with approximately 75% of the land as cropland (Table 12) and only 8%-11% in forest. This basically linear stream is separated by a very narrow fringe of trees and grass from the neighboring fields over most of its length. No known perturbations from feed lots occurred. Relief is low with a mean slope less than 0.7%. More than half of the fish were omnivores, about 25% were insectivores, and only about 10% were piscivores.

Mount's Run, on the other hand, contains a generally desirable fish community. The proximity of our sampling station here to E5 might assist in maintaining this population. Nearly 60% of the watershed is in rowcrops, much of it in the upper part of the watershed (Table 12). Most of the 9% forest is located in the lower watershed. Mount's Run differs from other Eagle Creek watersheds in having a high proportion of land devoted to "other" uses (31%), much of it as permanent grassland. Mount's Run also contained deep pools probably because of good riparian protection. The fact that the benthic community seems of lower quality than the fish may be an indication of an approaching change in character. The benthic community has erratically improved since 1978, however, and some previous insult may have occurred from which the stream is recovering. Overall, this stream appears to stand close to the transitional brink and any further agricultural pressure could lead to its conversion to a minnow-dominated system.

Upper Eagle Creek supported a good fish community. Perhaps the fact that the watershed and stream were considerably larger than other units contributed positively despite the large portion in cropland (69%). As with Mount's Run, much of the forests were concentrated in the lower portion of the watershed.

School Branch and upper Finley were similar in both land use and fish communities, although the former was much more active in suburban construction.

Little Eagle Creek is influenced not only by 72.4% of cropland but also from septic tank drainage and channel reconstruction. Much of the forested areas (13%) are located in the lower end of the watershed.

The macroinvertebrate populations at Eagle Creek differed considerable from one station to another. Populations at Fishback (E2) and upper Eagle Creeks (E5) most resembled those from Rattlesnake Creek in composition and seasonal changes. Surber samples regularly included 10 to 15 families of insects, although certain families found at Rattlesnake Creek were not collected from Eagle Creek even here. Diversity values generally exceeded 1.5. School Branch (E1) and Little Eagle Creek (E3) generally contained fewer families and lower diversity values, but temporal changes were similar to those in Rattlesnake Creek. Finley Branch (E4 and E8) and Mount's Run (E6) were quite similar in that changes in seasonal composition were much reduced. Chironomids and oligochaetes dominated during summer as well as spring, giving evidence of an abundance of fine organic sediment. Although a good representation of families was usually present in upper Finley and Mount's Run, most were represented by only a few individuals per sample. Diversity values were usually less than 1.3.

Lower Finley Branch was highly degraded by a landfill and chemical recycling facility. The benthic community averaged less than 10% of the biomass and 33% of the density of macroinvertebrates at E8. Of those organisms present Chironomidae were by far the most numerous.

The observed pattern of faunal change associated with the progressive agricultural development is summarized in Table 13, and for fish only in Figure 21. The terms "minimal", "moderate", and "heavy" are used subjectively in reference to the degree to which the stream fauna appears to be influenced. The fauna of a hypothetical small forested Indiana stream has already been described. The establishment and gradual conversion of the watershed to rowcrops and animal herds changes the stream fauna little at first. We speculate that increased nutrient and organic inputs bolster detritivore populations such as chironomids and bluntnose minnow which, in turn, may improve the food base of insectivores and piscivores and lead to increased standing crops of fish without changing the basic trophic structure or seriously affecting most faunal groups.

As more of the watershed is converted into plowed fields or pastures, however, the rate of delivery of both nutrients and sediment to streams increases (Harrold, et.al. 1962, Likens and

Table 13: Summary of community characteristics under different intensities of agriculture.

	Degree of Agricultural Development		
Characteristic	Minimal	Moderate	Heavy
Macroinvertebrates			
Shannon diversity (density of insect families)	more than 1.5	1.3 to 1.5	less than 1.3
Number of insect families	12 to 15	8 to 12	8
Chironimidae (temporal pattern)	High in May & June Low in July & August	Relatively high throughout summer	dominant group throughout summer
Oligochaeta (density)	Low	fluctuating	high
Other families (density)	High	declines for uncommon families	declines for all families
Hydropsychidae	dominant throughout summer	common, but not always dominant	present in low numbers
Ephemeroptera	large numbers in May	present	irregularly present
Fish			
Standing crop	50-150 Kg/ha.	100-300 Kg/ha.	200-300 Kg/ha.
Centrarchids	20-30%	20-30%	10%
Insectivores	40-60%	40-60%	25-40%
Omnivores + Detritivores	10-25%	10-25%	40-50%
Herbivores	10%	10-30%	10-30%
Shannon diversity (no.)	2.0-2.5	1.8-2.0	1.8-2.0

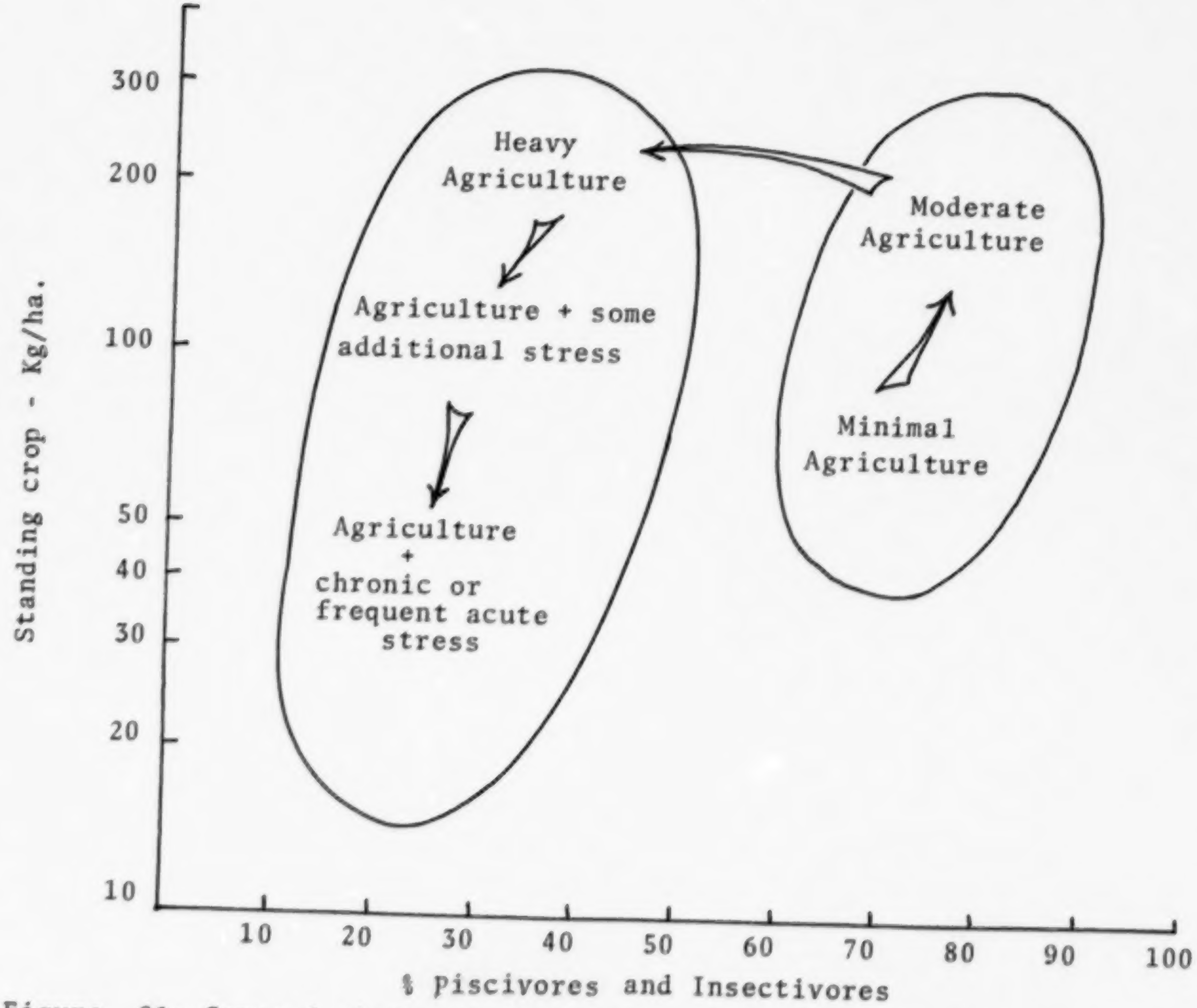

Figure 21: General change in fish communities of small midwestern streams under agricultural development of a watershed.

Bormann 1975). The range of effects on stream ecosystems has been thoroughly summarized by Farnworth, et. al. (1979). Macrobenthic populations become dominated by chironomids and oligochaete worms during the summer months as well as in the spring. Bass, other centrarchids, and darters become reduced, perhaps because of reduced reproductive success. This reduction of predation permits an expansion of the minnows. Redhorse and hog suckers soon become reduced also, and the fish community shifts sharply to dominance by omnivores, detritivores, and herbivores without changing the standing crop. This shift first occurs in the more vulnerable, smaller tributaries of a watershed without influencing lower portions of larger streams.

Additional periodic stress produced by animal feed lots, direct disturbance of the stream by pastured animals, and chronic localized influences further depress the fish and benthic populations.

The characteristics of the fish and benthic communities were examined in relation to water quality (Hyde, et. al. 1982). Each set of biological data (i.e., each of 6 sampling periods for fish and 13 for benthos) was compared with cropland, forests, and pasture in Eagle Creek watershed (Table 11) and Stotts Creek (Table 12) using Spearman's rank correlation. No relationships were noted between forest cover and the fish data, probably because of small differences among the sub-watersheds. A strong negative relationship was found between rankings of percent cropland in the sub-watersheds and percent piscivores and insectivores (P+I) in the fish population (Table 4). Sub-watersheds which contained more cropland were consistently characterized by lower percentages of piscivores and insectivores. Spearman's correlation coefficient was - .714 for the Eagle Creek system and - .90 for Stotts Creek, both significant at the .05 level. Variations in the amount of cropland within sub-watersheds accounted for 51% of the variation in P+I in Eagle Creek and 81% in Stotts Creek. We have extended these analyses and found statistically significant negative correlations between % cropland vs (a) mean depth (-.912) and (b) insect diversity (-.771) in Eagle Creek.

Because of the paucity of water quality data taken with the biological samples, the precise physical and chemical causes linking land use and aquatic communities were not identified. We speculate that runoff, sediment, and nutrient delivery to streams all increase gradually as agriculture expands in a watershed creating altered habitat and water quality and causing the observed biotic changes. As fields impinge on stream banks and the strip of protective riparian vegetation narrows, light and thermal regimes change and the stream channel widens and becomes more shallow. Sediment fills in pools and sifts into spaces between gravel. These alterations occur irregularly through time and space, thus defying precise description and identification.

The problems of determining water quality and loadings of nutrients and sediment from several sites in both watersheds are detailed by Huggins, et. al. (1982), who found that a large proportion of the runoff, nitrate, sediment N, sediment P, and suspended solids occurred in one or two quarters of each year during large storm events. Losses of suspended solids from land to the stream were estimated to average 700 kg/ha/yr from upper Finley Creek (near E8) and 1260 kg/ha/yr from the South Branch of Stotts Creek (near S7) from late 1979 to mid-1981. Sediment losses from both watersheds were far greater than the 25 kg/ha/yr estimated to occur from undisturbed deciduous forests (Likens, et. al. 1970, Johnson and Swank 1973). Sediment yields from two selected sub-watersheds within South Stotts Creek were estimated to exceed 3000 kg/ha/yr. The larger loading from the South Stotts Creek, despite having only about 53% as cropland, compared to the Finley Creek site (about 75% cropland), was explained by its having much more steeply sloping lands, an average of 3% with localized areas in excess of 20%. Unfortunately, estimates from watersheds having good biotic communities were not obtained.

In order to slow deleterious biotic changes or, as is the case with many segments of Eagle and Stotts Creeks, to improve the biotic community several measures can be taken. The most obvious is (1) the control of animal feed lot effluents and lagoons which are the most common cause of fishkills in many states including Indiana. Unreported sublethal events no doubt heavily influence stream ecosystems generally. (2) Control sedimentation of water systems by erosion control measures. It is unrealistic to suppose that there will be any future reduction in the extent of agriculture, but it may be possible to reduce or at least stabilize the intensity of agricultural contributions to streams by instituting appropriate BMPs.

Huggins, et. al. (1982) used the Finley Creek data and the ANSWERS model to estimate the potential water quality impacts of various mixes of BMPs including parallel terraces (PTO) and conservation tillage (chisel plowing and no-till planting) applied generally and at specific sites. Different scenarios projected sediment reductions of from 11% to 36% at costs estimated at $2.42 to $5.05/tonne reduced. Further reductions could result from the application of appropriate BMPs to critical areas. Hays (1982) documents the attempt of SCS(USDA) to promote BMPs in Eagle and Stotts watersheds, a critically important element in the overall MIP effort. The acceptance of new management practices was contingent upon improved crop productivity or reduced production costs. The pressure to adopt conservation tillage is substantial and improved water quality should accompany these changes in tillage practices.

Another area which was not regarded as agriculturally important, but which we believe is ecologically vital is (3) the preservation of an adequate buffer zone between cropland and streams. Permanent riparian forests function importantly to stabilize banks and reduce erosion, in maintaining proper water temperature, and in maintaining desirable stream channel characteristics. The specific ecological role played by riparian vegetation in both terrestrial and aquatic ecosystems deserves much more attention. In particular it is essential to determine for various stream situations what constitutes a desirable width for riparian vegetation, since it is here that the goals of the farmer and the goals of those advocating water quality improvement are most in conflict.

SUMMARY

1. From 1978 through 1980 fish and macroinvertebrate communities were examined from three watersheds ranging from predominately forested to heavily agricultural.

2. In addition to biotic communities, riparian vegetational patterns, stream morphology and habitat were examined. These investigations were coordinated with concomitant studies on land use and soil loss simulation studies.

3. Fish populations at 14 sites were sampled twice each summer with an electric seine. Estimates of standing crop, obtained by the DeLury method, and several community parameters were examined in relation to the intensity of agricultural development.

4. Standing crop estimates of fish were not, in themselves, of great value in evaluating chronic agricultural effects. Depressions in standing crop occurred in response to sporadic influences by animal feed lots and also to a chronic problem downstream from a chemical recycling plant and land fill.

5. Standing crop and the proportion of piscivores (centrarchids) and insectivores appear to best indicate the extent to which sustained agriculture affects the fish community. Moderate agriculture permits an expansion of the standing crop while maintaining good populations of sunfish, crappie, and bass. Heavy agriculture ultimately causes great declines in centrarchids and catostomids, and an expansion of omnivores, detritivores, and herbivores, first in smaller streams and then progressing downstream.

6. A statistically significant negative relationship was found between percent cropland in watersheds and percent piscivores and insectivores (% P+I) in the fish communities. The amount of cropland in sub-watersheds occounted for 51% of the variation in % P+I in Eagle Creek and 81% in Stotts Creek. Statistically significant negative relationships also occurred between % cropland and mean depth and between % cropland and insect diversity.

7. Three Surber samples of macroinvertebrates were collected monthly from May through October. Biomass was not a reliable indicator of environmental conditions, but diversity based upon density of insect families was useful.

8. The best collecting stations generally yielded from 10 to 20 insect families. Chironomids were major components of all locations during May and June, but declined in importance in July and August in the "good" sites while remaining abundant in the "poor" sites. Trichoptera, especially Hydropsychidae, became the dominant insect group following the decline in Chironomidae.

9. Point-source disturbances altered the taxonomic composition by eliminating or severely reducing usually uncommon families and the overall diversity, while increasing numbers of Chironomidae, Oligochaeta, and Nematods. Heavy agricultural leads to a depression in density of non-chironomid insects.

10. Recovery from a single event was rapid, while chronic depressions in the macroinvertebrate community occurred in areas of high agricultural utilization.

11. The presence of a vegetative buffer between agricultural fields, including grazed pastures, residential areas, or meadows and a stream is very important to the stream ecosystem. The smaller the stream the more important is this buffer strip.

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APPENDIX A

Stream Habitat Ratings

Table A-1. Description of categories used in measuring and rating stream habitat.

		rank number and category description				
Dimension		1	2	3	4	5
Mean depth	Range(cm)	5-15	16-25	26-35	36-45	45
	description	shallow	shallow-moderate	moderate	moderate-deep	deep
Bottom substrate	diameter(mm)	0.06	0.06-4.0	4.0-64	64-256	256
	description	silt-mud	sand-granule	pebble	cobble	boulders
Current	description	very slow	slow	moderate	fast	very fast
Cover	parameters	0 trees: submerged roots 0 trees submerged	0-1 trees: submerged roots 0-1 trees submerged	1-2 trees: submerged roots 1-2 trees submerged	2-3 trees: submerged roots 2-3 trees submerged	3 trees: submerged roots 3 trees submerged
	description	poor	fair	good	very good	excellent
Canopy		0% coverage	0-25% coverage	25-50% coverage	50-75% coverage	75-100% coverage
	description	poor	fair	good	very good	excellent

Table A-2. Mean habitat structure values for all study sites during the summer of 1978.

Score	Site	Description
11	S7	shallow-moderate, sand-granule, slow flow, fair cover, good canopy.
11	S9	shallow, sand-granule, moderate flow, fair cover, good canopy.
12	E4	shallow-moderate, silt-mud, slow flow, good cover, very good canopy.
13	S1	moderate depth, sand-granule, slow flow, good cover, good canopy.
13	S5	moderate depth, cobble, slow flow, good cover, good canopy.
13	E8	shallow-moderate, silt-mud, slow flow, good cover, excellent canopy.
14	R2	moderate-deep, sand-granule, slow flow, good cover, good canopy.
14	E2	shallow-moderate, cobble, moderate flow, fair cover, good canopy.
14	E6	moderate-deep, sand-granule, moderate flow, fair cover, good canopy.
14	E1	shallow-moderate, sand-granule, slow flow, good cover, excellent canopy.
15	R1	shallow-moderate, pebble, moderate flow, fair cover, excellent canopy.
15	S3	moderate depth, sand-granule, fast flow, very good cover, good canopy.
16	E3	moderate depth, cobble, slow flow, good cover, very good canopy.
17	E5	moderate-deep, pebble, slow flow, very good cover, very good canopy.

APPENDIX B

Summary of Fish Data

Table B-1: List of fishes collected by electrofishing in Rattlesnake, Stotts, and Eagle Creeks during 1978, 1979, and 1980.

Family and Scientific Name	Common Name
Petromyzontidae (lampreys)	
Lampetra lamottei	American brook lamprey
Icthyomyzon unicuspis	Silver lamprey
Icthyomyzon castaneus	Chestnut lamprey
Clupeidae (herrings)	
Dorosoma cepedianum	Gizzard shad
Esocidae (pikes)	
Esox americanus vermiculatus	Grass pickerel
Cyprinidae (minnows)	
Cyprinus carpio	Carp
Carassius auratus	Goldfish
Semotilus atromaculatus	Creek chub
Phoxinus erythrogaster	Southern redbellied dace
Phenocobius mirabilis	Suckermouth minnow
Hybopsis amblops	Bigeye chub
Notropis umbratilis	Redfin shiner
Notropis chrysocephalus	Striped shiner
Notropis whipplei	Steelcolor shiner
Notropis spilopterus	Spotfin shiner
Notropis stramineus	Sand shiner
Notropis volucellus	Mimic shiner
Ericymba buccata	Silverjaw minnow
Rhinichthys atratulus	Blacknose dace
Pimephales notatus	Bluntnose minnow
Campostoma anomalum	Stoneroller
Catostomidae (suckers)	
Catostomus commersoni	Common white sucker
Hypentelium nigricans	Northern hog sucker
Minytrema melanops	Spotted sucker
Moxostoma anisurum	Silver redhorse
Moxostoma duquesnei	Black redhorse
Moxostoma erythrurum	Golden redhorse
Moxostoma macrolepidotum	Shorthead redhorse
Erimyzon oblongatus	Creek chubsucker

Table B-1: (continued)

Family and Scientific Name	Common Name
Ictaluridae (Freshwater catfishes)	
Ictalurus melas	Black bullhead
Ictalurus natalis	Yellow bullhead
Noturus miurus	Brindled madtom
Cyprinodontidae (killifishes)	
Fundulus notatus	Blackstripe topminnow
Atherinidae (silversides)	
Labidesthes sicculus	Brook silversides
Centrarchidae (sunfishes)	
Ambloplites rupestris	Rock bass
Lepomis gulosus	Warmouth
Lepomis cyanellus	Greensunfish
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Micropterus dolomieui	Smallmouth bass
Micropterus Punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Pomoxis nigromaculatus	Black crappie
Percidae (perches)	
Etheostoma nigrum	Johnny darter
Etheostoma spectabile	Orangethroat darter
Etheostoma caeruleum	Rainbow darter
Etheostoma flabellare	Fantail darter
Etheostoma blennioides	Greenside darter
Percina caprodes	Logperch
Percina maculata	Blackside darter
Cottidae (sculpins)	
Cottus bairdi	Mottled sculpin

Table B-2: Fish caught at Stotts Creek-S1

Species	No.	% No.	Wt.(KG)	% Wt.
Yellow Bullhead	1	0.05	0.020	0.12
Brindled Madtom	1	0.05	0.001	0.01
White Sucker	83	4.55	3.242	19.54
Northern Hogsucker	55	3.02	1.304	7.86
Silver Redhorse	1	0.05	0.030	0.18
Black Redhorse	39	2.14	2.673	16.11
Golden Redhorse	44	2.41	1.268	7.64
Spotfin Shiner	21	1.15	0.123	0.74
Sand Shiner	158	8.67	0.249	1.50
Mimic Shiner	1	0.05	0.001	0.01
Bluntnose Minnow	583	31.98	1.144	6.89
Stoneroller	282	15.47	0.898	5.41
Creek Chub	122	6.69	0.777	4.68
Blacknose Dace	5	0.27	0.010	0.06
Suckermouth Minnow	4	0.22	0.020	0.12
Silverjaw Minnow	184	10.09	0.308	1.86
Striped Shiner	126	6.91	1.466	8.84
Green Sunfish	9	0.49	0.071	0.43
Bluegill	6	0.33	0.023	0.14
Longear Sunfish	6	0.33	0.157	0.95
Smallmouth Bass	7	0.38	2.574	15.51
Largemouth Bass	3	0.16	0.119	0.72
Spotted Bass	4	0.22	0.004	0.02
Greenside Darter	5	0.27	0.011	0.07
Fantail Darter	1	0.05	0.001	0.01
Johnny Darter	15	0.82	0.019	0.11
Rainbow Darter	18	0.99	0.019	0.11
Orangethroat Darter	26	1.43	0.028	0.17
Redfin Shiner	13	0.71	0.032	0.19
Totals- 29 Species	1823	100.00	16.592	100.00

Table B-3: Fish caught at Stotts Creek-S3

Species	No.	% No.	Wt.(KG)	% Wt.
Yellow Bullhead	8	0.20	1.183	3.70
Brindled Madtom	4	0.10	0.010	0.03
White Sucker	151	3.71	3.470	10.84
Northern Hogsucker	127	3.12	4.818	15.05
Silver Redhorse	1	0.02	0.075	0.23
Black Redhorse	31	0.76	1.716	5.36
Golden Redhorse	5	0.12	0.377	1.10
River Redhorse	3	0.07	0.504	1.57
Emerald Shiner	1	0.02	0.001	0.00
Spotfin Shiner	7	0.17	0.030	0.09
Sand Shiner	91	2.24	0.138	0.43
Mimic Shiner	5	0.12	0.008	0.02
Bluntnose Minnow	796	19.56	1.745	5.45
Stoneroller	1176	28.90	4.619	14.43
Creek Chub	471	11.58	4.894	15.29
Blacknose Dace	15	0.37	0.020	0.06
Suckermouth Minnow	14	0.34	0.041	0.13
Silverjaw Minnow	366	8.99	0.745	2.33
Striped Shiner	425	10.44	4.473	13.97
Steel Shiner	1	0.02	0.001	0.00
Green Sunfish	25	0.61	0.192	0.60
Bluegill	17	0.42	0.141	0.44
Longear Sunfish	15	0.37	0.442	1.38
Smallmouth Bass	9	0.22	1.025	3.20
Largemouth Bass	4	0.10	0.978	3.05
Spotted Bass	2	0.05	0.017	0.05
Greenside Darter	17	0.42	0.030	0.09
Fantail Darter	6	0.15	0.006	0.02
Johnny Darter	62	1.52	0.071	0.22
Rainbow Darter	62	1.52	0.069	0.22
Orangethroat Darter	137	3.37	0.150	0.47
Redfin Shiner	11	0.27	0.017	0.05
Miscellaneous/ Unidentified	4	0.10	0.010	0.03
Totals- 33 Species	4069	100.00	32.016	100.00

Table B-4: Fish caught at Stotts Creek-S5

Species	No.	% No.	Wt.(KG)	% Wt.
Gizzard Shad	3	0.15	0.260	0.90
Black Bullhead	2	0.10	0.142	0.49
Yellow Bullhead	4	0.21	0.357	1.24
Carp	1	0.05	1.500	5.19
White Sucker	221	11.36	7.808	27.02
Northern Hogsucker	12	0.62	0.841	2.91
Black Redhorse	5	0.26	0.236	0.82
Golden Redhorse	9	0.46	0.234	0.81
Spotfin Shiner	1	0.05	0.002	0.01
Sand Shiner	2	0.10	0.005	0.02
Bluntnose Minnow	381	19.59	2.267	7.85
Stoneroller	691	35.53	5.232	18.11
Creek Chub	115	5.91	2.156	7.46
Blacknose Dace	1	0.05	0.001	0.00
Silverjaw Minnow	13	0.67	0.036	0.12
Striped Shiner	123	6.32	1.552	5.37
Warmouth	1	0.05	0.008	0.03
Green Sunfish	97	4.99	1.654	5.72
Bluegill	39	2.01	0.261	0.90
Longear Sunfish	11	0.57	0.299	1.03
Smallmouth Bass	15	0.77	2.213	7.66
Largemouth Bass	11	0.57	1.477	5.11
Spotted Bass	12	0.62	0.054	0.19
Redear Sunfish	1	0.05	0.005	0.02
Greenside Darter	29	1.49	0.071	0.25
Fantail Darter	10	0.51	0.018	0.06
Johnny Darter	33	1.70	0.048	0.17
Rainbow Darter	42	2.16	0.063	0.22
Orangethroat Darter	52	2.67	0.068	0.24
Redfin Shiner	7	0.36	0.009	0.03
Creek Chubsucker	1	0.05	0.019	0.07
Totals- 31 Species	1945	100.00	28.896	100.00

Table B-5: Fish caught at Stotts Creek-S7

Species	No.	% No.	Wt.(KG)	% Wt.
Yellow Bullhead	1	0.04	0.001	0.01
Brindled Madtom	6	0.22	0.015	0.16
White Sucker	71	2.59	0.613	6.71
Northern Hogsucker	13	0.47	0.327	3.58
Black Redhorse	4	0.15	0.071	0.78
Golden Redhorse	10	0.36	0.074	0.81
Spotfin Shiner	2	0.07	0.013	0.14
Sand Shiner	22	0.80	0.034	0.37
Bluntnose Minnow	383	13.96	0.605	6.62
Flathead Minnow	1	0.04	0.002	0.02
Stoneroller	919	33.49	2.747	30.07
Creek Chub	555	20.23	2.820	30.87
Blacknose Dace	35	1.28	0.070	0.77
So. Redbelly Dace	6	0.22	0.020	0.22
Silverjaw Minnow	142	5.17	0.236	2.58
Striped Shiner	97	3.53	0.724	7.93
Green Sunfish	10	0.36	0.072	0.79
Bluegill	11	0.40	0.075	0.82
Longear Sunfish	3	0.11	0.065	0.71
Largemouth Bass	1	0.04	0.002	0.02
Spotted Bass	13	0.47	0.016	0.18
Greenside Darter	36	1.31	0.055	0.60
Fantail Darter	11	0.40	0.039	0.43
Johnny Darter	103	3.75	0.109	1.19
Rainbow Darter	114	4.15	0.117	1.28
Orangethroat Darter	156	5.69	0.167	1.83
Redfin Shiner	19	0.69	0.045	0.49
Totals- 27 Species	2744	100.00	9.134	100.00

Table B-6: Fish caught at Stotts Creek-S9

Species	No.	% No.	Wt.(KG)	% Wt.
Black Bullhead	1	0.04	0.010	0.09
White Sucker	199	8.68	2.770	24.22
Northern Hogsucker	20	0.87	0.224	1.96
Spotfin Shiner	3	0.13	0.009	0.08
Sand Shiner	16	0.70	0.022	0.19
Bluntnose Minnow	392	17.10	0.920	8.04
Stoneroller	523	22.81	3.107	27.16
Creek Chub	345	15.05	2.430	21.24
Blacknose Dace	67	2.92	0.138	0.21
So. Redbelly Dace	3	0.13	0.007	0.06
Silverjaw Minnow	234	10.20	0.412	3.60
Striped Shiner	70	3.05	0.492	4.30
Green Sunfish	6	0.26	0.046	0.40
Bluegill	9	0.39	0.189	1.65
Smallmouth Bass	1	0.04	0.154	1.35
Spotted Bass	11	0.39	0.013	0.11
Greenside Darter	14	0.61	0.027	0.24
Johnny Darter	158	6.89	0.165	1.44
Rainbow Darter	20	0.87	0.020	0.17
Orangethroat Darter	196	8.55	0.243	2.12
Redfin Shiner	5	0.22	0.011	0.10
Totals- 20 Species	2293	100.00	11.439	100.00

Table B-7: Fish caught at Eagle Creek-E1

Species	No.	% No.	Wt.(KG)	% Wt.
Gizzard Shad	6	0.65	0.066	0.85
Black Bullhead	51	5.53	0.087	1.12
Brook Silversides	1	0.11	0.002	0.03
Carp	1	0.11	0.002	0.03
White Sucker	52	5.64	0.898	11.54
Bluntnose Minnow	34	3.69	0.180	2.31
Stoneroller	91	9.87	0.506	6.50
Creek Chub	249	27.01	3.049	39.17
Silverjaw Minnow	7	0.76	0.046	0.59
River Chub	1	0.11	0.012	0.15
Striped Shiner	7	0.76	0.080	1.03
Green Sunfish	7	0.76	0.085	1.09
Bluegill	29	3.15	0.062	0.80
Longear Sunfish	12	1.30	0.224	2.88
Largemouth Bass	12	1.30	0.155	1.99
White Crappie	1	0.11	0.012	0.15
Spotted Bass	10	1.08	0.024	0.31
Greenside Darter	2	0.22	0.006	0.08
Johnny Darter	21	2.28	0.050	0.64
Logperch	76	8.24	1.086	13.95
Orangethroat Darter	99	10.74	0.164	2.11
Mottled Sculpin	152	16.49	0.979	12.58
Redfin Shiner	1	0.11	0.009	0.12
Totals- 23 Species	922	100.00	7.784	100.00

Table B-8: Fish caught at Eagle Creek-E2

Species	No.	% No.	Wt.(KG)	% Wt.
Yellow Bullhead	2	0.10	0.052	0.19
White Sucker	111	5.51	5.755	21.27
Spotfin Shiner	1	0.05	0.004	0.01
Bluntnose Minnow	386	19.16	1.035	3.83
Stoneroller	538	26.70	3.590	13.27
Creek Chub	361	17.92	6.847	25.31
Suckermouth Minnow	2	0.10	0.030	0.11
Silverjaw Minnow	4	0.20	0.006	0.02
Striped Shiner	134	6.65	4.557	16.85
Rockbass	8	0.40	0.374	1.38
Green Sunfish	55	2.73	0.439	1.62
Bluegill	61	3.03	2.849	10.53
Longear Sunfish	3	0.15	0.064	0.24
Largemouth Bass	4	0.20	0.109	0.40
Spotted Bass	8	0.40	0.019	0.07
Johnny Darter	100	4.96	0.216	0.80
Logperch	58	2.88	0.811	3.00
Blackside Darter	9	0.45	0.037	0.14
Dusky Darter	5	0.25	0.042	0.16
Orangethroat Darter	128	6.35	0.159	0.59
Redfin Shiner	36	1.79	0.047	0.17
Creek Chubsucker	1	0.05	0.010	0.04
Totals- 22 Species	2015	100.00	27.052	100.00

Table B-9: Fish caught at Eagle Creek-E3

Species	No.	% No.	Wt.(KG)	% Wt.
Black Bullhead	10	0.32	0.205	0.52
Yellow Bullhead	2	0.06	0.071	0.18
White Sucker	175	5.63	10.551	26.94
Spotted Sucker	1	0.03	0.230	0.59
Bluntnose Minnow	758	24.38	2.989	7.63
Stoneroller	778	25.02	6.902	17.62
Creek Chub	657	21.13	11.269	28.78
Silverjaw Minnow	53	1.70	0.245	0.63
Striped Shiner	143	4.60	2.422	6.18
Green Sunfish	57	1.83	0.698	1.78
Bluegill	23	0.74	0.574	1.47
Longear Sunfish	107	3.44	2.171	5.54
Largemouth Bass	2	0.06	0.015	0.04
Spotted Bass	8	0.26	0.014	0.04
Greenside Darter	1	0.03	0.002	0.01
Johnny Darter	153	4.92	0.266	0.68
Rainbow Darter	3	0.10	0.009	0.02
Orangethroat Darter	101	3.25	0.120	0.31
Mottled Sculpin	1	0.03	0.020	0.05
Redfin Shiner	76	2.44	0.388	0.99
Totals- 20 Species	3109	100.00	39.161	100.00

Table B-10: Fish caught at Eagle Creek-E4

Species	No.	% No.	Wt.(KG)	% Wt.
Grass Pickerel	2	0.49	0.020	0.50
Black Bullhead	4	0.99	0.041	1.02
Yellow Bullhead	4	0.99	0.228	5.67
White Sucker	31	7.64	0.655	16.28
Bluntnose Minnow	57	14.04	0.187	4.65
Flathead Minnow	1	0.25	0.002	0.05
Stoneroller	83	20.44	1.293	32.13
Creek Chub	150	36.95	1.071	26.62
Silverjaw Minnow	1	0.25	0.001	0.02
Striped Shiner	11	2.71	0.043	1.07
Green Sunfish	9	2.22	0.109	2.71
Bluegill	7	1.72	0.129	3.21
Longear Sunfish	1	0.25	0.006	0.15
Largemouth Bass	5	1.23	0.105	2.61
Spotted Bass	6	1.48	0.031	0.77
Johnny Darter	7	1.72	0.008	0.20
Logperch	1	0.25	0.010	0.25
Orangethroat Darter	8	1.97	0.010	0.25
Mottled Sculpin	10	2.46	0.038	0.94
Redfin Shiner	3	0.74	0.009	0.22
Creek Chubsucker	5	1.23	0.028	0.70
Totals- 21 Species	406	100.00	4.024	100.00

Table B-11: Fish caught at Eagle Creek-E5

Species	No.	% No.	Wt.(KG)	% Wt.
Gizzard Shad	23	2.00	1.110	2.08
Grass Pickerel	16	1.39	0.785	1.47
Black Bullhead	2	0.17	0.130	0.24
Carp	6	0.52	6.385	11.98
White Sucker	136	11.85	19.029	35.70
Spotted Sucker	7	0.61	2.148	4.03
Golden Redhorse	6	0.52	1.830	3.43
Bluntnose Minnow	291	25.35	0.727	1.36
Stoneroller	150	13.07	1.612	3.02
Creek Chub	68	5.92	3.659	6.86
Striped Shiner	75	6.53	2.217	4.16
Rockbass	37	3.22	6.314	11.85
Green Sunfish	5	0.44	0.077	0.14
Bluegill	10	0.87	0.386	0.72
Longear Sunfish	48	4.18	1.484	2.78
Smallmouth Bass	1	0.09	0.144	0.27
Largemouth Bass	14	1.22	1.860	3.49
White Crappie	34	2.96	1.929	3.62
Black Crappie	2	0.17	0.130	0.24
Spotted Bass	5	0.44	0.051	0.10
Johnny Darter	47	4.09	0.070	0.13
Logperch	59	5.14	0.760	1.43
Blackside Darter	1	0.09	0.006	0.01
Rainbow Darter	45	3.92	0.077	0.14
Orangethroat Darter	35	3.05	0.038	0.07
Mottled Sculpin	3	0.26	0.015	0.03
Redfin Shiner	9	0.78	0.019	0.04
Creek Chubsucker	13	1.13	0.310	0.58
Totals- 28 Species	1148	100.00	53.302	100.00

Table B-12: Fish caught at Eagle Creek-E6

Species	No.	% No.	Wt.(KG)	% Wt.
Silvery Lamprey	4	0.24	0.029	0.17
Grass Pickerel	29	1.73	1.204	7.11
Yellow Bullhead	20	1.19	0.259	1.53
Carp	2	0.12	0.134	0.79
White Sucker	18	1.07	1.314	7.76
Bluntnose Minnow	161	9.58	0.470	2.78
Stoneroller	420	24.99	2.182	12.89
Creek Chub	208	12.37	2.026	11.97
Suckermouth Minnow	1	0.06	0.003	0.02
So. Redbelly Dace	5	0.30	0.008	0.05
Silverjaw Minnow	5	0.30	0.008	0.05
Striped Shiner	253	15.05	5.171	30.55
Rockbass	14	0.83	1.042	6.16
Green Sunfish	9	0.54	0.130	0.77
Bluegill	10	0.59	0.181	1.07
Longear Sunfish	24	1.43	0.674	3.98
Smallmouth Bass	2	0.12	0.002	0.01
Largemouth Bass	7	0.42	0.364	2.15
White Crappie	18	1.07	1.006	5.94
Spotted Bass	2	0.12	0.007	0.04
Johnny Darter	95	5.65	0.135	0.80
Logperch	5	0.30	0.077	0.45
Rainbow Darter	99	5.89	0.131	0.77
Orangethroat Darter	206	12.25	0.208	1.23
Mottled Sculpin	63	3.75	0.151	0.89
Creek Chubsucker	1	0.06	0.010	0.06
Totals- 26 Species	1681	100.00	16.926	100.00

Table B-13: Fish caught at Eagle Creek-E8

Species	No.	% No.	Wt.(KG)	% Wt.
Gizzard Shad	3	0.23	0.028	0.15
Grass Pickerel	11	0.85	0.243	1.29
Black Bullhead	5	0.39	0.377	2.01
Yellow Bullhead	2	0.15	0.115	0.61
White Sucker	110	8.51	4.995	26.58
Spotted Sucker	1	0.08	0.124	0.66
Silver Redhorse	4	0.31	0.140	0.75
Bluntnose Minnow	58	4.49	0.314	1.67
Stoneroller	154	11.91	1.716	9.13
Creek Chub	417	32.25	7.790	41.46
Silverjaw Minnow	3	0.23	0.011	0.06
Striped Shiner	28	2.17	0.158	0.84
Green Sunfish	13	1.01	0.352	1.87
Bluegill	18	1.39	0.429	2.28
Longear Sunfish	2	0.15	0.049	0.26
Largemouth Bass	3	0.23	0.010	0.05
White Crappie	4	0.31	0.200	1.06
Spotted Bass	5	0.39	0.054	0.29
Johnny Darter	182	14.08	0.327	1.74
Rainbow Darter	13	1.01	0.028	0.15
Dusky Darter	6	0.46	0.012	0.06
Orangethroat Darter	139	10.75	0.240	1.28
Mottled Sculpin	91	7.04	0.824	4.39
Redfin Shiner	1	0.08	0.002	0.01
Creek Chubsucker	20	1.55	0.252	1.34
Totals- 25 Species	1293	100.00	18.790	100.00

Table B-14: Fish caught at Rattlesnake Creek-R1

Species	No.	% No.	Wt.(KG)	% Wt.
American Brook Lamprey	3	0.25	0.015	0.11
Grass Pickerel	14	1.15	0.228	1.69
White Sucker	5	0.41	0.480	3.55
Northern Hogsucker	47	3.86	2.832	20.94
Black Redhorse	8	0.66	0.973	7.19
Spotfin Shiner	4	0.33	0.017	0.13
Sand Shiner	6	0.49	0.010	0.07
Mimic Shiner	1	0.08	0.002	0.01
Bluntnose Minnow	168	13.80	0.425	3.14
Stoneroller	46	3.78	0.251	1.86
Creek Chub	182	14.95	2.240	16.56
Blacknose Dace	4	0.33	0.020	0.15
Suckermouth Minnow	18	1.48	0.129	0.95
Silverjaw Minnow	55	4.52	0.175	1.29
Striped Shiner	192	15.78	1.324	9.79
Bigeye Chub	31	2.55	0.099	0.73
Rockbass	49	4.03	3.460	25.58
Green Sunfish	4	0.33	0.021	0.16
Bluegill	3	0.25	0.006	0.04
Longear Sunfish	14	1.15	0.182	1.35
Smallmouth Bass	3	0.25	0.006	0.04
Largemouth Bass	4	0.33	0.033	0.24
Spotted Bass	2	0.16	0.007	0.05
Redear Sunfish	1	0.08	0.005	0.04
Greenside Darter	15	1.23	0.044	0.33
Johnny Darter	49	4.03	0.056	0.41
Blackside Darter	6	0.49	0.016	0.12
Rainbow Darter	175	14.38	0.176	1.30
Orangethroat Darter	22	1.81	0.023	0.17
Mottled Sculpin	64	5.26	0.225	1.66
Redfin Shiner	19	1.56	0.036	0.27
Creek Chubsucker	3	0.25	0.008	0.06
Totals- 32 Species	1217	100.00	13.524	100.00

Table B-15: Fish caught at Rattlesnake Creek-R3

Species	No.	% No.	Wt.(KG)	% Wt.
American Brook Lamprey	12	0.74	0.100	0.29
Silver Lamprey	4	0.25	0.163	0.48
Grass Pickerel	2	0.12	0.004	0.01
White Sucker	5	0.31	0.007	0.02
Northern Hogsucker	114	7.03	5.481	16.02
Black Redhorse	109	6.72	9.237	27.00
Golden Redhorse	39	2.40	4.421	12.92
Spotfin Shiner	29	1.79	0.086	0.25
Sand Shiner	61	3.76	0.071	0.21
Mimic Shiner	2	0.12	0.004	0.01
Bluntnose Minnow	109	6.72	0.295	0.86
Stoneroller	383	23.61	2.791	8.16
Creek Chub	91	5.61	1.279	3.74
Suckermouth Minnow	2	0.12	0.007	0.02
Silverjaw Minnow	95	5.86	0.206	0.60
Bullhead Minnow	12	0.74	0.024	0.07
Striped Shiner	128	7.89	1.523	4.45
Bigeye Chub	4	0.25	0.010	0.03
Steel Shiner	4	0.25	0.017	0.05
Rockbass	60	3.70	4.021	11.75
Green Sunfish	11	0.68	0.081	0.24
Bluegill	8	0.49	0.055	0.16
Longear Sunfish	104	6.41	2.045	5.98
Smallmouth Bass	5	0.31	0.848	2.48
Largemouth Bass	8	0.49	1.041	3.04
Spotted Bass	1	0.06	0.036	0.11
Orange Spotted Sunfish	1	0.06	0.005	0.01
Redear Sunfish	1	0.06	0.004	0.01
Greenside Darter	9	0.55	0.032	0.09
Johnny Darter	96	5.92	0.104	0.30
Blackside Darter	1	0.06	0.001	0.00
Rainbow Darter	37	2.28	0.049	0.14
Orangethroat Darter	25	1.54	0.034	0.10
Mottled Sculpin	40	2.47	0.099	0.29
Redfin Shiner	1	0.06	0.004	0.01
Miscellaneous/ Unidentified	9	0.55	0.027	0.08
Totals- 36 Species	1622	100.00	34.212	100.00

APPENDIX C

Summary of Surber Sampler Data

Table C-1. Relative abundance of benthic macroinvertebreates from Surber collections (*less than 0.01%).

Taxon	Rattlesnake Creek		Stotts Creek		Eagle Creek	
	% No	% Wt	% No	% Wt	% No	% Wt
Phylum: Annelida	5.06	0.39	4.49	3.38	4.84	1.37
Class: Oligochaeta	3.53	0.30	3.59	3.11	4.12	0.95
Order: Haplotaxida	0.03	0.02	0.84	0.55	0.68	0.14
Family: Tubificidae	0.03	0.02	0.84	0.55	0.45	0.14
Order: Lumbriculida	-	-	0.26	0.01	*	0.02
Class: Hirudinea	0.08	0.01	0.26	0.01	0.09	0.16
Phylum: Mollusca	0.70	12.87	0.24	1.77	2.00	15.60
Class: Gastropoda	0.52	10.62	0.14	0.24	0.73	1.07
Family: Ancylidae	0.04	0.05	0.06	0.02	0.47	0.09
Physidae	0.02	0.04	0.04	0.02	0.11	0.26
Lymnaeidae	0.14	8.39	0.01	0.01	0.11	0.29
Pleuroceridae	0.04	2.01	-	-	-	-
Hydrobiidae	0.17	0.13	-	-	-	-
Planorbidae	-	-	-	-	0.03	0.36
Class: Pelecypoda	0.17	2.25	0.10	1.53	1.26	14.52
Phylum: Arthropoda	92.03	86.52	94.26	94.79	91.37	82.77
Class: Arachnida	0.09	0.05	0.01	*	0.04	0.02
Order: Acarina	0.01	*	*	*	*	*
Araneida	-	-	*	*	*	*
Family: Tetragnathidae	-	-	*	*	-	-
Class: Crustacea	0.22	53.51	1.45	15.40	0.73	13.17
Order: Amphipoda	0.03	0.02	-	-	0.01	0.03
Family: Talitridae	0.02	0.01	-	-	0.01	0.03
Order Isopoda	0.01	*	1.34	0.61	0.60	0.23
Family: Sphaeromidae	-	-	0.96	0.41	0.39	0.61

Table C-1: (continued).

Taxon	Rattlesnake Creek		Stotts Creek		Eagle Creek	
	% No	% Wt	% No	% Wt	% No	% Wt
Class: Crustacea (continued)						
Order: Decapoda	0.17	53.48	0.12	14.79	0.12	12.94
Family: Astacidae	0.17	53.48	0.12	14.79	0.12	12.80
Class: Insecta	91.73	32.96	92.79	79.39	90.58	69.58
Order: Ephemeroptera	8.75	5.12	13.85	3.81	11.15	1.11
Family: Baetidae	4.37	1.52	10.02	1.82	9.83	0.80
Heptageniidae	2.33	0.88	3.07	1.79	0.39	0.16
Tricorythidae	0.01	0.00	-	-	0.01	*
Caenidae	0.05	0.01	0.57	0.12	0.81	0.10
Ephemeridae	0.07	0.07	-	-	-	-
Siphlonuridae	1.80	2.55	0.06	0.07	0.06	0.04
Ephemerellidae	0.03	0.01	-	-	0.04	0.01
Baetiscidae	0.04	0.07	-	-	*	*
Potamanthidae	-	-	*	*	-	-
Leptophlebiidae	-	-	*	*	0.01	*
Order: Odonata	0.07	0.44	0.05	0.27	0.03	0.17
Family: Aeshnidae	0.02	0.31	0.01	0.18	*	0.04
Calopterygidae	0.02	*	0.02	0.07	-	-
Gomphidae	0.02	0.13	*	*	*	*
Coenigrionidae	-	-	0.02	0.02	0.01	*
Macromiidae	-	-	-	-	*	0.11
Order: Plecoptera	0.61	0.19	0.35	0.19	0.63	0.20
Family: Perlidae	0.12	0.13	0.16	0.17	0.41	0.17
Caphiidae	0.01	*	*	*	*	*
Chloroperlidae	0.01	*	-	-	*	*
Nemouridae	-	-	*	*	-	-
Order: Hemiptera	0.21	0.11	0.06	0.05	0.10	0.02
Family: Corixidae	-	-	0.01	*	*	*
Gerridae	0.03	0.03	*	0.03	0.02	*
Veliidae	0.03	0.02	0.01	0.01	-	-
Saldidae	-	-	*	*	*	*
Nepidae	-	-	-	-	0.05	0.01

Table C-1: (continued).

Taxon	Rattlesnake Creek		Stotts Creek		Eagle Creek	
	% No	% Wt	% No	% Wt	% No	% Wt
Family: Mesovliidae	-	-	-	-	*	*
Notonectidae	-	-	-	-	*	*
Hebridae	-	-	-	-	*	*
Order: Neuroptera	1.23	4.18	-	-	*	*
Family: Corydalidae	1.23	4.18	-	-	-	-
Sisyridae	-	-	-	-	*	*
Order: Coleoptera	4.86	5.57	5.03	0.90	9.41	1.34
Family: Haliplidae	-	-	0.08	0.01	*	*
Dytiscidae	0.03	0.01	0.01	*	0.02	*
Hydrophilidae	0.34	0.63	0.05	0.01	0.02	*
Psephenidae	2.77	2.00	*	*	0.35	0.07
Dryopidae	0.17	0.36	0.02	0.04	*	*
Elmidae	1.30	1.66	4.12	0.80	8.83	1.23
Helodidae	-	-	0.73	0.01	-	-
Gyrinidae	0.21	0.86	0.01	*	-	-
Staphylinidae	-	-	*	*	*	*
Ptilodactylidae	0.02	0.02	-	-	-	-
Chrysomelidae	-	-	-	-	*	*
Order: Trichoptera	24.85	10.71	35.76	67.57	27.12	9.17
Family: Hydropsychidae	14.86	5.32	32.78	67.02	22.43	7.86
Hydroptilidae	0.18	0.05	0.10	0.02	1.37	0.23
Limnephilidae	0.09	0.84	-	-	-	-
Phryganeidae	0.07	0.02	*	*	-	-
Rhyacophilidae	0.49	0.33	-	-	*	0.05
Leptoceridae	0.02	0.01	0.03	0.02	*	*
Polycentopodidae	0.34	0.16	0.01	*	0.07	0.02
Philopotamidae	6.05	2.06	0.08	0.40	1.91	0.80
Glossosomatidae	0.12	0.14	-	-	-	-
Helicopsychidae	0.02	0.04	-	-	0.01	*
Order: Diptera	51.08	6.64	37.65	6.55	42.11	57.58
Family: Tipulidae	1.44	3.01	2.40	4.18	0.16	53.11
Ceratopogonidae	1.17	0.10	0.20	0.02	0.07	*

Table C-1: (continued)

Taxon	Rattlesnake Creek		Stotts Creek		Eagle Creek	
	% No	% Wt	% No	% Wt	% No	% Wt
Family: Chironomidae	39.78	1.60	29.21	1.42	42.11	1.94
Simuliidae	6.15	0.40	4.23	0.38	10.49	2.35
Empididae	0.68	0.09	0.39	0.05	0.42	0.04
Tabanidae	0.11	1.27	0.03	0.29	0.01	*
Dolichopodidae	0.01	*	*	*	-	-
Dixidae	0.01	*	*	*	-	-
Chaoboridae	-	-	0.03	0.03	*	*
Psychodidae	-	-	*	*	0.03	*
Stratiomyidae	-	-	*	*	0.01	*
Culicidae	-	-	*	*	*	*
Rhagionidae	-	-	*	*	-	-
Order: Collembola	0.07	0.01	0.04	0.06	-	-
Phylum: Coelenterata	0.04	*	*	*	-	-
Phylum: Porifera	-	-	-	-	*	0.09
Phylum: Platyhelmenthes	0.02	*	*	*	0.48	*
Phylum: Nematoda	2.15	0.21	1.00	0.06	1.30	0.07
Total samples	71		262		293	

APPENDIX D

Width and Depth Characteristics of Study Streams

Table D-1: Comparison of mean pool depth and relative pool depth of the uppermost and lowermost sites of Eagle Creek and Stotts Creek watersheds with mean pool depth and relative pool depth of the uppermost and lowermost sites on Rattlesnake Creek.

Site	Mean Depth(M)	Rel. Depth(%)	% Diff.
	Eagle Creek		
Uppermost Pool	0.27	36	29
Lowermost Pool	0.48	65	
	Stotts Creek		
Uppermost Pool	0.33	47	6
Lowermost Pool	0.37	53	
	Rattlesnake Creek		
Uppermost Pool	0.97	100	32
Lowermost Pool	0.66	68	

Table D-2: Comparison of the mean pool depth, cumulative mean pool depth, and mean pool width of individual streams of the Eagle Creek and Stotts Creek watersheds with mean pool depth and mean pool width of individual sites and the cumulative mean pool depth of Rattlesnake Creek.

Stream Site	Mean Pool Depth (M)	Cumulative Mean Pool Depth (%)	Mean Pool Width (M)
		Eagle Creek	
Fishback Creek	0.45	61	5.5
Mounts Run	0.45	61	4.7
Eagle Creek	0.41	56	14.4
Little Eagle Creek	0.40	54	9.5
Finley Creek	0.32	43	4.9
School Branch	0.25	34	2.6
$\overline{X}$	0.38	52	6.9
		Stotts Creek	
Koots Fork	0.50	71	3.1
South Prong Stotts	0.49	70	6.1
Stotts Creek	0.36	51	9.3
Lost Creek	0.34	49	5.5
Buck Creek	0.24	35	2.9
North Prong Stotts	0.23	33	6.5
Henderson Creek	0.19	28	4.2
$\overline{X}$	0.34	48	5.4
		Rattlesnake Creek	
R-6	0.97	100	9.3
R-4	0.76	78	6.0
R-2	0.66	68	7.5
R-3	0.38	39	5.5
R-5	0.24	25	6.2
	0.60	62	6.9